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The Journal *of* Orthopædic Surgery

DISCUSSION OF THE INDICATIONS, TECHNIQUE AND RESULTS OF TRANSPLANTATION IN GUNSHOT INJURIES OF NERVES.

BY MAJOR T. P. McMURRAY, LIVERPOOL.

Mr. President and Gentlemen:

THE subject of tendon transplantation in nerve injuries is an immense one, and, moreover, it is one which is growing in importance every day, and we are seeing, more and more, cases in which this method of procedure is applicable. At first we thought—and most of us were taught,—that every suture of a nerve we could accomplish would be followed by complete recovery; we thought we should see the function coming back in the limb. And then we began to find that in numbers of cases after three or four years there was no recovery of function. We did not know the reason of that failure; we had got the suture accomplished, as we thought, successfully, and we had felt certain there ought to have been recovery. But this kind of case is coming back day after day, and bringing a tremendous amount of work, and so the question of nerve suture has to be squarely faced. Another type of case is that in which at the operation there is no possibility of bringing about end-to-end suture. The percentage of cases in which the result is unsatisfactory varies according to the particular nerve injured. In the case of such a nerve as the median, the number, or the proportion, in which end-to-end suture cannot be achieved is very small. If you have a case in which the median nerve in the arm is injured at the bend of the elbow, flexion of that elbow will fill in a gap of three inches. In the case of musculo-spiral injury, you find that with flexion and adduction of the arm there are at least 5% in which it is impossible to get anything like end-to-end apposition. I have had

about ten cases in which it has been impossible to get this apposition, and I have tried various methods of filling in the gap in the nerve. The first method was by taking a cutaneous nerve which was of less importance and implanting it between the divided ends. Secondly, we took a tube of fat and put the end of the nerve in this tube of fat and then a tube of fascia round that. But none of those, I am sorry to say, has been successful. I have watched these cases for over a year after I have carried this out, but in no case, after a year, or even 18 months, has there been a sign of recovery. That class of case, obviously, should have something else done. If we know the prognosis is so bad that there is practically no hope of recovery of the nerve by any means which does not include end-to-end suture, we realize that something else should be done at once.

Then we have those cases which, with the nerve destruction, have also a lot of muscle loss. We frequently find, in cases of gunshot wound of the back of the forearm, in which the posterior interosseous, or the lower part of the musculospiral is injured, that in addition the upper part of the muscles of the forearm have been shot away. No nerve suture, in such a case as that, would be of advantage, even though the nerves were capable of being brought into apposition; there is no muscle to carry out the function.

The tendon transplantations which can be done with advantage vary very greatly according to the nerves involved. If we take these tendon transplantations in turn, we find that the nerve most frequently injured is the musculo-spiral which may be injured in any of its parts. It is most frequently hurt at the back of the humerus, in association with a compound fracture of that bone. In such a case you may get a nerve which has laid there for one or two years after a compound fracture; the nerve has been lying in the midst of sepsis, without any attempt at suture having been made, or perhaps being possible, for a year. Even though, in such cases, we may get end-to-end apposition, the nerve is unlikely to recover. We find a septic compound fracture of the humerus, with a discharging wound, and then, at the time of the operation, we find that nothing can be done to suture the nerve, because of the loss of tissue. Then tendon transplantation holds out the only hope for recovery of function in the arm.

Consider the muscles which can be transplanted in the forearm. On the front, there is the flexor carpi radialis and the flexor carpi ulnaris. These have only one action, that is, flexion of the wrist with the fingers extended. Consider how often in flexion of the wrist the muscles I have named can be done without. Sherrington showed us that with any

action of a group of muscles producing a given movement of a joint, you have a reflex inhibition of other muscles. In extension of the wrist there is a reflex inhibition of the muscles which produce flexion. Therefore every time the wrist is extended by the extensor carpi radialis the flexors are thrown out of action by inhibition from the nerve centre. The only position of strength for the hand is with the hand dorsi-flexed. That is the position for withstanding strain, and when that position is taken up, we realize how one of the muscles can be done without. Then there are the pronators and supinators. Let us take the pronator radii teres. It is possible to pronate without the pronator radii teres; you equalize the two groups much better by doing without it; in spastic hemiplegia the arm is held in a position of fixed pronation, and the only way to get supination is by division of the pronator radii teres. We know that division of this is not followed by weakness, and therefore we can do without it. Here then are three muscles which can be done without. The only other muscle which can be done without is the palmaris longus. In at least one out of ten cases that muscle is not present; it is a very variable muscle; sometimes it is present and strong, sometimes it is absent. Wherever it is present, it may be used for transplantation. So there are four muscles which can be done without, but one of them is unreliable. The other three can be dispensed with without loss of power.

Now with regard to the technique of tendon transplantation in cases of the musculo-spiral nerve injury. We are going to transplant into the dorsal aspect to produce two things, dorsi-flexion of the wrist, and extension of the fingers. It is not enough to have only extension of the fingers, you must have with it, extension of the wrist. The only tendon which can be used to produce that dorsi-flexion of the wrist properly is the pronator radii teres. Various other operations have been devised but none of them will produce dorsi-flexion. As we know, the pronator radii teres will produce it. The pronator radii teres is inserted into the middle of the shaft of the radius, just under cover of the supinator longus. It is not inserted in the ordinary way. It does not become progressively narrower, it is a broad flat tendon, and is inserted by a broad base into the outer surface of the radius. The tendon is only about half an inch in length, and if it is to be raised up from the radius, it must be taken up completely, because part of the muscle is of no use at all; you must have the whole. And you cannot take that muscle completely away without taking also its periosteum. The incision which we employ is the long J-shaped incision along the radial border, parallel to the supinator longus, curving round over the back of the

wrist joint, and curving up on the inner border of the forearm for three inches. Its upper border on the radial side extends just above the insertion of the pronator radii teres. The full flap is turned back. I have never seen such a flap slough, not even at the edge, nor has it caused trouble. The pronator radii teres is taken off the radius, with its periosteum. And here I might mention that we have taken a series of X-ray pictures a year after operation, and not one case has shown a bony deposit in the periosteum. So the trouble of there being a subsequent bony deposit does not seem to come into the scope of the operation at all. If the extensor carpi radialis longior alone is acting, unless you insert the radii teres into both the extensor radialis brevior and longior, you cannot have true extension of the wrist; it must pass through and act on both muscles.

Further down, we take the flexor carpi radialis from its insertion as low down as possible, and the flexor carpi ulnaris as low as we can, too. In the flexor carpi radialis you have a long, thin tendon five inches in length; in the flexor carpi ulnaris you have a tendon 1½ to 2 inches in length in its upper surface, and ¾ inch on its deep surface. These two tendons are taken and brought round to the dorsal aspect. It is easy, after dividing the flexor carpi radialis, to bring this tendon to the dorsal aspect. If you try to bring the ulnaris round by only dividing its insertion, you find it is adhering to the inner border of the ulna by muscle fibres, therefore you must divide that attachment for three inches from its insertion. This is the only way you can produce a straight line from the origin to the insertion of the newly transplanted tendon. The whole secret in connection with tendon transplantation in the forearm is the avoidance of angling of the tendons, just as it is the secret of tendon transplantation anywhere else. If you make small incisions and do not deal with the whole course of the tendon, you are almost certain to have angling of the tendon, which, as I say, is what we have to be careful to avoid. If such angling results you are not likely to have success. A transplanted tendon will not work round a hook of bone, or fascia; it must take a straight line from origin to insertion. It is for that reason that the long incision has been advocated. These two tendons, then, are brought round to the dorsal aspect of the forearm and brought obliquely. The flexor carpi radialis is inserted into the two extensors of the thumb and the extensor of the index finger. There are three extensors of the thumb. The extensor longus pollicis is not essential. You will find in musculo-spiral nerve paralysis that the patient can straighten out the end of his thumb; this is not due to the action of the extensor longus muscle, it is due to the muscles of the

thenar eminence, therefore it is associated with adduction. We find that the thumb and index finger always work together in the normal movements of the hand. And if we arrange for extension of the thumb and of the index finger to be carried out by one transplanted tendon, and extension of the other fingers to be carried out by the other, you will find the result satisfactory. This is the best grouping for purposes of function. After those tendons have been brought round to the dorsal aspect, they can be inserted into the extensors in three different ways. The first way is to split the tendon, and pass one half under the receiving tendon, and the other half above it. The two ends are joined beyond the receiving tendon, and each half of the transplanted tendons sutured to the receiving tendon. That leaves one raw surface above, and one below. And in order to produce a strong union you must make the surface of the receiving tendon raw, because a raw surface on a tendon is the only way to get it to unite. If two raw surfaces are brought together, they unite and become strong, whereas two shiny surfaces will not unite; they will show a marked tendency to slide. The second method of transplantation is to take the three receiving tendons, and divide them from their muscles, leaving the three ends free. Pass these three ends through the transplanted tendon at different levels, and bury their ends in this. The third method, which is not so good, is to split the transplanted tendon into three, and insert one of each of the three divisions into one of each of the three receiving tendons. I say that this method is not so good. and I say so because it is so liable to cause adhesions as compared with the other methods. In this case, you see, you are leaving three or four raw surfaces open. It is the same with the flexor carpi ulnaris. This tendon is very small but strong, and if you split that tendon and pass it round one half on either side of the receiving tendons and join the bare ends together, you can easily suture these three receiving tendons to the raw surface of the transplanted tendon. When that is done, you will find there is no necessity to wrap any fascia, or fat, or mucous membrane round any of those junctions, if the simple expedient of covering in the raw ends of the transplanted tendons is adhered to. But if you leave raw surfaces, you will get adhesions. The line of suture is then closed up with two layers; first deep fascia, then skin. After closure of the wound, the patient is left with the wrist and fingers in the dorsi-flexed position. The fingers are never left hyper-extended. Most of these injured hands, such as are seen so often in hospitals and which have taken so many months to cure, have been put on flat splints, with the palm spread out and the fingers

hyper-extended. It is found that it takes months to bend those fingers, because they have been so long in a position of hyper-extension. The way in which a dorsi-flexion wrist splint should be put on is with the fingers in slight flexion, that is to say about 10 degrees of flexion at each joint, the metacarpo-phalangeal joint at 10°, and so on, each with slight flexion. There will be no stiffness if you take care to keep that position. But there certainly will be stiffness if the hand is forced out with the fingers hyper-extended. Of all the transplantations of tendons in any part of the body, that for musculo-spiral paralysis is the most successful. This is because the three tendons which we use are always constant and always strong. There is, of course, no use in transplanting a tendon which is not capable of doing work, that is to say, one which will not do the particular work you want it to do. Therefore the median and ulnar muscles must be strong before you even suggest transplanting. There must be complete control of the flexor aspect of the forearm before you try to get control of the extensor aspect. I have myself done 25 of these cases of musculo-spiral paralysis, and in not one of them has the man been unable to go back to his work. One of the patients, who was a private, has now got a commission. Nine months after the operation was done he passed the full gymnastic course, and he has now been out in France a year, and has been wounded slightly. That will indicate sufficiently that the hand he got after the operation was a useful one; it was the right hand, and he was perfectly able to do all his normal work, as before. We have got, downstairs, two cases, and presently you will be able to see what they look like. You will see that the men can close the fist, extend the fingers, dorsi-flex the wrist, and that extension is not passive but active.

The next nerve lesion to be considered is complete destruction of the ulnar. We know that, frequently, the ulnar is destroyed over a long part of its course, and usually this is accompanied with a badly comminuted condition of the internal condyle of the humerus. If we transplant that ulnar nerve in front of the internal condyle, we can close in a gap of at least four inches. If there is a bigger distance than that, it is impossible to close in the gap without dividing the nerve to the flexor carpi ulnaris and the deeper part of the flexor profundus. You frequently come to a point, by flexion of the wrist, at which you cannot pull the ulnar nerve any more without dividing these two little branches. Then the question is whether you will sacrifice the muscles of the hand. Can you hope to get the muscles of the hand back by transplantation, or will you have to sacrifice two branches of the nerve? You frequently find yourself up against this point, and you have to come

to a decision. You must sacrifice either the muscles of the forearm or the muscles of the hand. If there is a mobile hand, it is best to leave the flexor carpi ulnaris and the flexor profundus, because when the ulnar nerve is destroyed it may leave a very good hand, in fact it does so in the majority of cases. With that treatment you are able to get a mobile hand, without, perhaps, as much strength as before, but far better than would have resulted if you had destroyed the ulnar profundus nerve supply. The ulnar nerve is sometimes found to have gone entirely; far up, the branches to the flexor carpi ulnaris and the flexor profundus are also gone, and it is impossible to get the two ends together. Then arises the question whether anything can be done for the patients with this condition. Very little can be done for them, but very little is necessary in cases of ulnar nerve paralysis. In at least 75% of these cases the patient has a hand which is perfectly useful, and nothing operative is needed; the man can do his normal work, and can get through that normal work perfectly well. But in some of the cases there is complete loss of flexion of the little finger, and in some there is also complete loss of power to flex the ring finger. In these cases, a long straight incision is made along the flexor aspect of the forearm. You first come on the flexor sublimis. That is pulled in, and you get down to the flexor profundus. Then you find the two outer tendons of the flexor profundus which are innervated by the median nerve, and the two inner which are innervated by the ulnar nerve; and it is the simplest thing to suture the two inactive tendons to the two outer active ones. Then you have the outer part of the flexor profundus, which is supplied entirely by the median nerve, acting on the inner part, which was inactive before. That, as far as tendon transplantation goes, is as much as we can do in ulnar paralysis.

Now with regard to median paralysis. Complete destruction of the median nerve is a rare event, that is to say, destruction so bad that we cannot get the end-to-end apposition that we want. But a median nerve paralysis which has existed as long as 2½ and even 3 years without recovery is not rare. We know that at the Pensioners' Outpatient department we get a lot of pensioners, dozens of cases, in which function of nerves has not come back after they have been sutured 18 months or two years. In a lot of those cases the nerve injured is the median. I am not yet able to speak definitely of the statistics, because they are in the making. The suture of the nerve seems to have been successfully done two or three years ago, but there has been no recovery.

We get, in these cases, a hand which is very much worse than in cases of ulnar paralysis. The thumb is useless, it will not flex, except that it can, perhaps, be adducted into the palm by the flexor brevis pollicis, with closure of the ring and little fingers, but usually no movement in the index finger. There may be trophic changes, but this is not common; there may be blueness, but not ulceration. In the median nerve cases, we can transplant one of the active extensors of the wrist, and the best of these to select for the purpose is the extensor carpi radialis longior. On the radial side of the wrist joint there are two extensors of the carpus. They both act in the same way, and one can be done without. Through an incision on the outer side, you can get at both the flexor longus pollicis tendon and the extensor carpi radialis longior tendon. The extensor carpi radialis longior is divided at the base of the second metacarpal, and it is brought forward under the supinator longus, or over it, whichever you please, to the anterior aspect of the forearm, and then is implanted into the flexor longus pollicis. Here we have two tendons which are practically the same size, and the problem is a totally different one from that of the insertion of the flexor carpi radialis and ulnaris in musculo-spiral cases. As these two tendons are practically equal, you should be able to make a suture which will leave the tendon edges quite smooth, without thickening or abruptness. And the best implantation here of one tendon into the other is the lateral implantation. By this transplantation you get a tendon which will act on the thumb and take the place of the flexor longus pollicis and it will act well, too. After such a procedure as this the thumb becomes a very useful member, which can be approximated to each of the other fingers.

Let us now take the shoulder joint. We find paralysis of the deltoid if the musculo-spiral is divided high up at its origin with the circumflex nerve; there is that paralysis in addition to complete paralysis of the extensors of arm and forearm. Here you have the shoulder joint completely paralysed, and you, naturally, try to suture your circumflex nerve, or suture the trunk at a place before the circumflex nerve comes off. If that proves to be impossible, you think of tendon transplantation. Tendon transplantation for this condition was done, of course, long before the war. Part of the trapezius was displaced from the clavicular and acromion, and attached over these to the deltoid. But none of the cases so treated was successful. The arms were useful when supported by splints, but that was all; there was no movement in the transplanted muscle, and there was never active abduction of the shoulder. So tendon transplantation in the case of paralysis of the

deltoid does not rank as a useful procedure. The best treatment is an arthrodesis of the shoulder. There is an active trapezius, and after arthrodesis all the muscles governing the scapula govern the upper arm.

We now come to the nerves of the lower limb. The first is the anterior crural. Cases of injury to this nerve we sometimes see in an orthopaedic hospital, but not very often, because the anterior crural nerve lies so close to the femoral artery and femoral vein, that any injury to it is likely to be accompanied by a bad injury to either the femoral artery or the femoral vein, and so to be accompanied by a fatal haemorrhage. We see a few cases in which there is paralysis of the quadriceps, usually partial. Of at least a dozen such cases I have seen, ten have recovered by rest, massage and electrical treatment, though at first they were, apparently, completely paralysed. The nerve could not have been completely divided. If there be a complete paralysis, it is necessary to do tendon transplantation in order to produce extension of the leg on the thigh. There are various muscles on the posterior aspect of the thigh, the strongest of them being the biceps. The biceps can be used by itself, or in combination with one of the muscles on the inner side of the thigh. The semitendinosus and gracilis can be used either alone, or both together. You should never use the semimembranosus for this purpose, because of its close association with the knee joint. The biceps is taken by a long incision over the course of the muscle down to its insertion into the head of the fibula. You must see that the line you get is a straight one; there must be a straight tendon between origin and incision. So you make your incision at least twelve inches long, from the head of the fibula upwards, completely freeing the biceps from its capsule, and separating the lower half of its deep head from its origin from the external supra-condylar ridge of the femur. Take the tendon forward, and bring it through a small hole above the patella It is then sutured into a groove in the patella, made with a chisel. The best way is to make a definite groove in the bone and lay the tendon in it, then completely close. If you use the biceps alone, it will give you extension of the leg, but it will also give you an outward pull on the patella, so you will then have a tendency to knock-knee, and there will be a liability for you to get a displacement outwards. It is better to use one of the muscles of the inner side to equalize the pull, and so pull the patella straight up. It is better to do that through a similar, or the same, incision. The semitendinosus is brought round the inner side, and sutured to the patella, in the same way, into a groove. Thus you have the biceps and the semitendinosus both producing extension of the leg on the thigh. The knee is kept straight for four to six

weeks, and you can use massage and electric treatment on the transplanted muscles, as soon as the stitches are taken out. In this way you get active movement, and gradually increasing active flexion starting after six weeks. Forced passive movements must not be given.

Next we come to the great sciatic, and its two branches. The external popliteal is frequently injured, and the site of such injury is, often near the head of the fibula. But by flexion of the knee joint you can bring the ends together, and usually you can get complete restoration of function. The prognosis after suture to the external popliteal is very good: in that respect it is like the musculo-spiral. Now, if there is no recovery in the external popliteal muscles, there is, as a result, a completely dropped foot. Here you need to produce not so much movement as strength. The first condition to be looked for in the lower limb is strength, whereas in the upper limb the desideratum is active movement. We can take any of the extensor muscles of the foot, on the anterior aspect of the leg, and attach their tendons to the tibia, so as to produce a foot which is held at a right angle, or slightly more. The usual muscles taken for this purpose are the tibialis anticus, and one of the peronei. If one of the peronei is pulled upon while it is behind the fibula, you will find that there it plantar flexes the foot. If you transplant it in front of the fibula, and pull, it no longer plantar flexes the foot but it still everts the foot by 15°. If you use the peroneus longus and tibialis anticus you slightly dorsi-flex the foot. These are not the best muscles to use. The peroneus brevis will evert the foot and hold it at right angles, whereas the peroneus tertius will evert the foot and dorsi-flex it; and if the peroneus tertius were strong enough, it would be the best muscle, but it is not. We know, of course, that these muscles which are transplanted show a tendency to stretch afterwards, therefore it is necessary to use the strongest tendons possible. And the best of all tendon fixations in the leg result from the use of the tibialis anticus and the peroneus brevis. The tibialis anticus is taken four inches above the ankle joint, just to the outer side of the anterior border of the tibia. Make a vertical incision and get down on the tendon, lift the periosteum from the bone, drill a hole through the bone into the medullary cavity from either side, and cut off your tendon about two inches above that hole. The hole should be two inches above the ankle joint, above the annular ligament. Put the lower end of the tendon through the hole, turn it back on itself, and suture it. In this way you have a loop of tendon passing through the bone. We know that this is a far better method of fixation than putting the tendon into a groove. The other way is by making a groove

in the bone and laying the tendon in it, and fixing it in that way to the periosteum. In the case of the peroneus longus or peroneus brevis muscle, you take it four inches above the lower end of the fibula, through an incision made over it. The tendon is divided through this upper incision, and is pulled through a lower incision, being then brought up alongside the tibialis anticus, underneath the anterior annular ligament, because this will leave a tendon which is held down in position, and which does not stand out. If you transplant the peroneus brevis and pull it tight across the ankle, you leave a tendon which stands out underneath the skin, and so is liable to irritation by the boot in walking. It is better to transplant the tendon underneath the annular ligament. You can fix it through the same hole in the tibia which has been already bored. In adults the hole which you have to bore is a big one if you transplant two tendons through it. It is, therefore, better to take the tendon through a new hole lower down, and transplant it in the opposite direction. You suture the peroneus longus to itself. If you wish you can join the upper end of the tibialis anticus to the course of the attached lower end, below the insertion into the tibia, so that if there is any recovery of function in your muscle, it will still act and dorsi-flex the foot. But you should not attempt tendon transplantation if you think there is a chance of recovery without it.

Internal popliteal paralysis can be treated in many ways. The way usually followed in children's hospitals is to supply a metal tongue to the boot, which will not allow dorsi-flexion, so that such a patient walks with that foot at right angles. If you can fix the foot at right angles it is better than obliging the patient to wear an instrument all the time. The best operation is to make an incision on the inner or outer border of the tendo Achillis, and fix this through a hole in the bone, in the same way as in the case of the tibialis anticus. In this case, you may leave half the tendo Achillis in its normal position, and transplant the other half and suture, holding the foot at right angles. And if you have, in the patient, recovery of function of the gastrocnemius and soleus, there is still plantar flexion action of the foot.

TENDON FIXATION IN IRRECOVERABLE MUSCULO-SPIRAL PARALYSIS.

BY A. ROCYN JONES, M.B., B.S., M.R.C.S.,

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THE idea of converting paralysed tendons into ligaments for the fixation of joints seems to have been first conceived by Tilanus of

Amsterdam in 1898. In that year he published a paper on tendon transplantation and reported upon some seven cases of paralytic deformities of the foot, upon which he had performed the operation. In one of these cases he attempted a kind of fixation. The patient was a girl aged thirteen, suffering from paralytic talipes equino-varus upon whom Tilanus operated on January 25, 1898. He first cut the tendo Achillis subcutaneously and afterwards did an open tenotomy of the extensor proprius hallucis attaching the central end to the extensor longus digitorum, and the peripheral end to the periosteum of the tibia by means of a silk suture. He then put the foot up in plaster of Paris and reported that he obtained a good result. Codivilla, however, was the first definitely to advocate the operation of tendon fixation. He was struck by the manner in which tendons were sometimes embedded in callus in cases of fracture and proceeded with his pupil, Sangiorgi, in 1900, to attempt to produce a similar result for the fixation of flail joints. In conjunction with his pupil he lifted a flap of periosteum and prepared a groove in the bone to receive the tendon, which was sewn down under proper tension and the periosteum brought over.

In 1903 Reiner introduced what he called tenodesis. He threaded the tendon with silk from bone to bone, for example, in paralytic talipes varus, a strong silk thread was passed through the base of the fifth metatarsal bone and tied, the two ends were then pleated along the peroneus brevis, which had been cut and brought from its bed to the front of the fibula. Simlarly, a second thread was fastened to the cuboid and its two ends guided, in and out, along the peroneus longus to the back of the fibula in which a hole was bored antero-posteriorly. These double threads were sent through the tunnel, thus prepared, in opposite directons and passed along a prepared groove on the outer surface of the bone and there tied.

In 1912, Gallie of Toronto adopted tendon fixation in paralytic deformities of the foot and three years later reported on a series of approximately one hundred cases with very gratifying results. Gallie incises the periosteum and, if an epiphysis be present, the perichondrium also. Periosteum and perichondrium are then raised on either side and a trough is gouged in the bone and cartilage. The foot is placed in the corrected position and the tautly drawn tendon is then laid in the groove, and a kangaroo tendon suture passed through cartilage and tendon and then tied, the tendon being firmly fastened. The periosteal edges are brought together with a catgut suture, the rest of the tendon being buried in the groove.

In partial paralysis with persistent deformity Gallie has also had

FIG. 1.—The fixed dorsiflexed attitude of the carpus and metacarpus.

FIG. 2.—Grasping a wooden mallet.

FIG. 3.—Lifting and holding a gas cylinder weighing over eight pounds.

A DISCHARGED SOLDIER UPON WHOM A TENDON FIXATION HAS BEEN PERFORMED FOR IRREPARABLE MUSCULO-SPIRAL PARALYSIS.

excellent results, by using half the tendon for the fixation and leaving the rest to functionate normally. For example in calcaneus, he splits the tendo Achillis longitudinally and at the upper end of the incision, cuts free the anterior half and then fixes and buries it in the tibia, locking the foot at rightangles.

Hitherto, the operation of tendon fixation has been confined to the lower limbs, owing partly to the greater frequency of poliomyelitis in these extremities. It has, however, a peculiar value in dropped wrist following injury of the musculo-spiral nerve, where the nerve on exploration is found to be beyond repair.

In such cases the grasping power of the hand and fingers is rendered feeble by the complete loss of muscle balance, and unless the carpus and metacarpus are steadied by the radial and ulnar extensors a powerful handgrasp is impossible. But by converting these three extensors into ligaments the carpus can be fixed in the best functional attitude of dorsi-flexion: and still permit movement at the wrist joint, but not in the direction of the deformity.

In performing the operation good exposure of these tendons can be obtained by a single three and a half inch incision commencing just above the back of the wrist joint and extending up the middle of the forearm. By retracting the extensor ossis metacarpi pollicis and the extensor brevis pollicis, the two radial extensors can be followed along the forearm, and their tendons divided high up, the ends being pulled down. A tunnel of a sufficiently wide bore to accommodate these somewhat thick tendons is then drilled right across the radius from the outer side, a little over an inch above the line of the wrist joint. The tendons are next scarified with a knife the better to promote union with bone and periosteum, and the extensor carpi radialis longior is afterwards led through the tunnel from the outer and the brevior from the inner side.

The hand is held well dorsi-flexed, and each emerging end is drawn taut with artery forceps and made to overlap the other extensor to which it is sewn with a continuous catgut suture. One or two sutures should be passed through tendon and periosteum. In the same way the extensor carpi ulnaris is followed up the forearm, divided, and its end taken, from within outwards, through a tunnel in the ulna at the same level as the radial extensor. The end is drawn taut and any tendency towards radial deviation of the hand by the pull of the radial extensor is corrected. The emerging portion overlaps the other part of the tendon, the two being sewn together with catgut. The skin incision is closed with horse hair and hand and forearm encased in

plaster of Paris. It is important that the hand be supported in the dorsi-flexed position from the time the first catgut suture is inserted until the last plaster bandage is applied. The stitches are removed in two or three weeks and a fresh plaster cast put on.

The plaster is discarded in two or three months from the time of the operation and the patient allowed to use his hand, but a wage earning employment is inadvisable for another six weeks.

In one case operated upon the periosteum on the radius was incised and elevated and instead of a tunnel a groove was gouged along the bone to receive one of the tendons, but there does not appear to be any particular advantage in this and it takes much longer than boring a tunnel through the bone. It is important to keep the bony attachments of the tendons separate and not allow them to enter the same aperture. With the tendons fixed as described, there is very little deviation from their natural path and therefore they exert a straight and direct pull on the hand.

The first case operated upon was a pensioner who sustained a gunshot wound of the right arm in May, 1916. He was admitted fourteen months later, in July, 1917, to the Royal National Orthopaedic Hospital with an old comminuted fracture of the middle of the shaft of the humerus with loss of bone, the fragments having been united in good alignment. He had in addition complete musculo-spiral paralysis and his right arm was therefore explored. The musculo-spiral nerve was found to be beyond repair,—about five inches being absent; the wound was therefore closed. On September 26, 1917, a tendon fixation was performed in the manner already described. The case has, therefore, been under observation for ten months and the tendon ligaments are still acting well, showing no signs of loosening or stretching, their points of attachment being indicated by prominences of the bones. The hand is held dorsal-flexed and although the extension of the fingers is limited to that produced by the lumbricals and interossei, it seems fairly adequate for most purposes. The patient can use the right hand almost as well as the left for dressing, feeding and weight lifting, and whereas before the operation he could not write, he can now do so. For the last four months he has been engaged at his pre-war employment which consists in driving a colliery haulage engine in which both hands are necessary for the pulling of levers.

Tendon fixation is recommended as an alternative procedure to tendon transplantation, or the two may be combined by first performing the fixation and then transplanting the carpal flexors to the extensors of the fingers and thumb. It would be wise to do so in two stages, per-

forming the transplantation two to three months after the fixation, thus avoiding an unduly prolonged and complicated operation with possible matting of the tendons. The writer has, however, no experience of the combined operation.

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DISCUSSION.

THE PRESIDENT: We have had two very interesting and instructive papers. I particularly agree with Mr. McMurray as to the importance of large incisions in these tendon transplantation cases. In the earlier cases of tendon transplantation I think many people did not realize that; certainly I did not do so myself. The consequence was that in many of the earlier cases the transplantation which was carried out was of very little use. Another point which, I agree with the first speaker, should be insisted on, is the importance of choosing for this work muscles of sufficient strength to do the work which will be expected of them. In the original operations of tendon transplantation for calcaneus, the peroneus longus was expected to do the work of the gastrocnemius, which, of course, was absurd. Mr. McMurray did not say very much about the question of sensation. Perhaps when he comes to deal with the subject further in his reply, he will tell us more about that, that is, as to whether he thinks the loss of sensation is not very important in ulnar paralysis. Both papers are open for discussion.

MR. G. R. GIRDLESTONE: There is one thing I would like to ask Mr. McMurray, and that is, whether he does not make sure what the power of passive hyperextension is before he transplants the muscles. One of the principles on which, I know, he works is, to make quite certain that the action of the tendon is perfectly easy and unopposed, before he transplants any tendon into it. Another thing is equally pertinent. He will say that he exercises the tendons which he is going to transplant before he transplants them. I am certain he makes the most use of flexors of the wrist in the workshops, before he transplants a tendon. I emphasize these two points because one sees cases of musculo-spiral paralysis in which there is contraction of the flexors, so that the fingers will not extend easily. And there are cases in which the flexor muscles are very weak. The hand has been kept in a splint for a long time and not exercised, so that when you ask such a man to grip and bend it, he does it very weakly. I am sure Mr. McMurray will tell us it is useless to transplant tendons until they have been got into a state of wholesome activity.

Occasionally it may be necessary even to lengthen a tendon. I had an interesting case in a man who was a professional golfer, as were also his father and his grandfather, in fact, all his ancestors were professional golfers. He told me he got into trouble at three years of age for swinging golf clubs in the street and hitting passers-by with them. The flexor longus pollicis was so contracted that it would not come out in any reasonable time, and in doing a transplantation it was necessary to lengthen the flexor longus pollicis before one could procure full extension of the thumb with any ease. He also had extremely strong

extensors of the wrist, with much bigger tendons than usual, and extraordinarily small extensors of the fingers, all, obviously, the result of swinging golf-clubs habitually and doing very little else.

I would like to mention one more point about musculo-spiral paralysis. Mr. McMurray said all cases of musculo-spiral paralysis could extend the terminal digit of the thumb. I have met with cases in which the patient could not do this. In those cases it must be important to transplant the tendons into the extensor secundi pollicis. It is necessary for the surgeon to make sure that the man can extend the terminal digit of his thumb before deciding on the transplantation. It is a question whether good cannot be done by tendon transplantation in brachial plexus injury, say, two or three years afterwards, where the hand is rather lacking, and no active adduction of the thumb is possible; also when a man tries to extend his hand and he cannot extend the terminal digit of his thumb. He often finds it impossible to adduct his thumb and extend the terminal digit. In two cases I inserted the extensor carpi radialis brevior into the extensor longus pollicis, and those men were able to extend the terminal digit of the thumb, though previously this had been possible to only a limited extent. I also tried to give one of them adduction of his thumb by taking the palmaris longus and inserting it by rolling up the fascia into the metacarpal bone, near its head, keeping it in that position for some time. But that became stretched, and the procedure was not a success. I wondered whether anybody had tried to get that position by removing the flexor longus pollicis from its present position and bringing it out, so that its action would be to abduct the thumb.

With regard to tendon fixation, Mr. McMurray said he put the foot at right angles. Sometimes it is felt that it is better to put it at 10 to 15° above a right angle, so as to allow for some subsequent lengthening of the tendons.

In reference to making two holes in the tibia, my own personal habit has been to make one hole, and bring the peroneus longus or brevis through the hole, and fixing it not to itself but to the tibialis anticus tendon, so as to avoid making two holes and having two loops.

MAJOR ELMSLIE: I felt rather sorry that Major McMurray did not introduce into his remarks, or preface his remarks, with some reference to the principles to be adopted or aimed at in tendon transplantation or tendon fixation. I feel that in pre-war days tendon transplantation is one of the subjects which, by proceedings sometimes carried out, has helped to get for orthopaedic surgery a bad name, because it has been advocated, perhaps, rather extensively, and has been utilized in many cases, I think, without proper consideration or forethought, first as to whether the tendons which were being transplanted could be so aligned as to carry out the new work intended, and, second, as to whether they had the power, in their transplanted position, to carry out the function required of them.

In transplanting a tendon, I think we should first make sure that transplantation is the only course possible, that is, that no recovery of function is possible in the muscle supplied by the nerve in question by any other means. I must confess I have had comparatively little experience of tendon transplantation, because I seldom encounter cases in which I think that procedure is fully justified. I do not do a transplantation until I am absolutely certain the nerve concerned has no possibility of recovery. Supposing we are satisfied on that point, that the nerve cannot recover, what other requirements should we investigate in the case? First, we should enquire are there any muscles which can be spared without loss of function? Second, is it possible to align these muscles in such a way that they can carry out the new function required of them? The third condition is: Have they the strength to carry out that function? The fourth condition I ought, perhaps, to have put earlier in order of importance. It is that we must settle in our minds exactly what it is we are going to require of these transplanted muscles. And that requirement will probably be different in every case of transplantation.

If I may take some examples, one is a kind of case which Major McMurray

left out, and which, in my experience, is the most successful transplantation of all, namely, the transplantation of muscles for a lesion of the posterior interosseous nerve beyond its point of supply to the extensor carpi radialis brevior. It is the kind of case where you have a paralysis of the extensor communis digitorum, and extensors of the thumb or, best of all, where there is paralysis of thumb muscles only, in the latter case from a wound of the back of the forearm, involving the lower branches of the posterior interosseous nerve, a lesion in which it is almost impossible to suture the branches of the nerve running to the thumb muscles. There is a paralysis of three thumb muscles, and you can spare individual muscles to replace each of those three separately. For instance, if the man has a palmaris longus, by transplantation of this, of the supinator longus, and one extensor of the radial side of the carpus, into the thumb, you can get absolutely complete replacement of every function of the thumb. That is the ideal tendon transplantation, where you are restoring the original function in every possible way. That, however, unfortunately, is a result which one can but seldom aim at.

In ordinary muscle transplantation what is our object? We cannot pretend to restore the extension of the wrist and fingers and thumb in absolute perfection as it was before. I feel that our object here is two-fold. The first is to give the patient voluntary extension of the wrist; the second, is to enable the patient to open out the fingers and thumb in such a position as to clear and open his grip. The trouble with musculo-spiral paralysis when the wrist is extended is that the fingers and wrist lie in *this* (demonstrated) position. It is not necessary in order to open your grip to be able to extend the wrist and fingers fully at the same time; it is sufficient if you can get the fingers out in a straight line, whilst the wrist is in a straight line with the forearm. I think *these* positions are essential. In transplanting for musculo-spiral paralysis you get a very full extension of the wrist by transplantation of the pronator radii teres into the extensors of the carpus. There is a further example in median nerve paralysis. I have not done transplantation in any case of median paralysis, but I think there is a future for it. But, again, we have to think out very carefully all the possible results we can get. My impression of complete median paralysis, where the hand is at its best, is that the man has a good general grip, that is, he can take hold of a good heavy object and hold it, he grips it with three fingers, and so can keep a good hold. But he has lost the movement of apposition of the first finger to the thumb, which is a very important one. Would it not be better, in a case of median paralysis, if we were to try to give the man an individual flexor of the index finger and of the thumb rather than combine the flexion of these fingers with those of other flexor tendons? My own feeling is that the movement, finger-to-thumb, is what we want to aim at in median paralysis. A further instance of thinking out the function which we propose for transplanting muscles is that of replacement of the quadriceps. Without the use of the quadriceps one can walk along level ground without there being any noticeable alteration in the gait. Many years ago our President, on an occasion when I went to the National Orthopædic hospital, showed me a boy who had been sent to his consulting room for transplantation to replace the quadriceps, because of infantile paralysis affecting that muscle, and he showed me how the boy walked up and down the room. One could not tell from his gait which was the paralyzed side. Mr. Little said he did not intend to transplant to replace the quadriceps. If we are going to transplant in order to replace the quadriceps what do we intend to do and with what object? To enable the patient to extend the flexed knee when his full weight is on the limb. I should like to ask those who have transplanted the biceps and other hamstrings into the quadriceps two questions: First, can your patients, after that transplantation, from a flexed knee position, come up straight; and, secondly, can they walk upstairs with a full action? If they can, the muscle has carried out its new function; if not, you might as well not have done the transplantation.

With regard to Mr. Rocyn Jones' tendon fixation in musculo-spiral paralysis, I would put to him again that question as to the function we want to carry out. His fixation keeps the wrist extended, but it does not enable the patient to clear the grip. As regards detail, there is a great deal that one might say

in criticism of Major McMurray's paper, but I do not wish to go into that—I prefer to concentrate on principles. Still, there is one point of detail which I would like to mention. Mr. McMurray alluded to transplantation to replace the deltoid and said it was a failure. Well, it is not a failure. The fact of the matter is that one seldom comes across a case in which it is possible to transplant to replace the deltoid, because either you are dealing, as we did in pre-war days, with cases of infantile paralysis in which the loss of the deltoid is only part of a wider paralysis in which the rest of the shoulder muscles are affected and in which, for that reason, it is difficult to get any muscle with sufficient strength to transplant, or else we are dealing with one in which there is a localized paralysis of the deltoid without injury to the shoulder joint and without injury to the surrounding structures, a kind of case so rare that I have not seen one. For a bullet to traverse the shoulder and catch the circumflex nerve without smashing the neck or the head of the humerus is a thing which it is almost impossible to believe. A few months ago I did a transplantation to replace a deltoid in a man who had complete loss of the deltoid from a wound in which the deltoid and the skin over it were cut right away. After the operation he can elevate his arm well above his head. Transplantation of the clavicular part of the pectoralis major is sufficient to replace all the anterior part of the deltoid and, if you have the supra-spinatus muscle left, the patient will get almost complete functional return in the shoulder. I go further than that and say the pectoralis major can carry out these functions in some cases and elevate the shoulder without transplantation at all. It is possible to replace the deltoid, but the cases which are suitable for transplantation are exceedingly rare.

CAPTAIN WINNETT ORR. I had prepared a paper on this subject for presentation to a session on nerve surgery, and that paper was presented by title only. But there were certain points in the paper which Captain McMurray gave us this morning, with details of surgical procedure and the anatomical relationships involved, which have been most interesting and which I would say a word about. In my paper I emphasized the fact that these procedures were particularly useful and applicable as soon as wounds were soundly healed in cases in which injury to muscles or tendons involved considerable loss of function, epecially in the hands. It is possible to restore to a hand which is almost entirely useless when it comes to the hospital useful functions which will enable the man to return to a useful occupation, by making use of the material left in the badly damaged arm. A number of the cases we have had at Cardiff have demonstrated this nicely. One case was that of a sailor, who went back to duty. He had a scar involving two-thirds of the dorsal surface of the arm. He had no ability to extend the fingers and, therefore, to do useful work. Transference of tendons enabled him to recover that ability to extend the fingers, and, as I say, he went back to duty. Pensioners come to us with the use of the hand apparently gone forever, but they can be made to carry out useful functions, and the movements can be restored by using tendons that are functioning.

There is one point which, I think, deserves special emphasis, although all these fundamental principles have been repeatedly emphasized, and that is, that in transferring these tendons, in addition to preserving movement, and procuring relaxation, etc., it is very important to deal with the transplanted tendons in such a way as to protect them, as far as possible, from adhesions. That, also, should be taken into account in making the incision in the first place, that is, one should so make the incision as to obviate that possibility.

With regard to the deltoid injuries, of which Major Elmslie spoke, it had been my intention to mention points which he has clarified, that in many of these cases in children recovery will take place without operation if the arm is maintained for a considerable period in a favourable position. The principles of that have been emphasized by Sir Robert Jones for years. It is very important to bear in mind that when the arm is in such a position that the deltoid is relaxed for a long time it will recover by the acquisition of a different function taken on by surrounding muscles.

In operating on the foot, I have used details of technique which I have found

useful and which save time. I do not undertake the passage of tendons by using a drill, but I take a mastoid chisel, by means of which a hole can be made in thirty to forty seconds, and the tendons can be passed through it with great ease.

I thank you for the privilege of attending here, and being allowed to say these few words.

MR. NAUGHTON DUNN: Stiffness of metacarpo-phalangeal joints suggests that there is room for discussion as to the time at which this operation should be undertaken. I do not think any tendon transplanting operation should be undertaken in the hand until we assure ourselves that all the potentialities for recovery are present, that is, until the patient can completely open and close his hand. For the purposes of transplantation we require strong muscles, and unless the joints which the muscles control allow free passive movement, the subsequent development cannot be complete. And if you are transplanting tendons, those of the same group will replace one another more efficiently than if you take them from another group. In the case of the foot, if you wish to use a tendon to invert the foot, where there is paralysis of the tibialis anticus, the peroneus tertius makes a more efficient inverter than one of the other peroneal muscles.

And I think the question of reëducation is one which might be more considered.

With regard to tendon fixation of the foot, I agree with Captain McMurray that the peroneus brevis is better than the peroneus longus for fixation.

MR. S. ALWYN SMITH: I quite agree with what Mr. Dunn said about the preparatory treatment before tendon transplantation is undertaken. I think that in the musculo-spiral cases which we see and which have lasted a considerable time, there is bound to be some limitation of movement in the metacarpo-phalangeal range, which should be overcome before anything operative is done. At the same time, a continual course of massage and faradism of the flexor muscle should be carried out. I have one case in regard to which I have waited three months to do a tendon transplantation, and the patient is not ready yet. He is a pensioner. He cannot flex the metacarpo-phalangeal joint beyond 30 degrees, even now. With regard to the anterior crural nerve [illegible] not agree with what Major Elmslie said about crural paralysis. The usual [illegible] of joint which you get in war-time surgery is totally different from that we used to meet with in the days of poliomyelitis, in which one or two branches going to and governing the crureus might be saved. I have had one case of gunshot wound of the groin, in which the missile came out at the sacro-iliac joint at the back. There was total paralysis, and the man could not walk. I waited for six to eight months, and nothing happened, and at the end of that time he was unable to put his foot to the ground. I did a tendon transplantation of the biceps on the outside and the semitendinosus, on the inner side, and after three months he had a very strong functioning extensor But as to his being able satisfactorily to pass the big test of being able to stand on one leg only, I do not think he could, nor do I think he will ever do so. But he could walk satisfactorily without an appliance.

With regard to gunshot wounds of the forearm involving the median nerve, I have transplanted the flexor carpi radialis to the flexor longus pollicis and the flexor profundus of the index finger. The function was good, but, unfortunately, the loss of sensation rather led to difficulties. The man was very pleased with himself at the end of six weeks, when he left. But he came back with a very bad trophic burn, the result of burning himself with a cigarette, and the usual consequences happened, that is to say, it took a very long time to clear up.

I think Major McMurray is rather optimistic about cases of paralysis of the ulnar nerve. We see a good many of these, and perhaps they are extra bad ones, especially in pensioners, those who have been to various orthopædic hospitals or centres, and who come back with the ordinary flexion deformities of the ring finger and little finger. I have never yet seen a case of ulnar paralysis which was able to return to military duty.

MAJOR ELMSLIE: May I have a word in order to explain? I have not, as a matter of fact, seen a case of anterior crural paralysis as a result of a gunshot wound, so I was not alluding particularly to military surgery, but rather to surgery in general. And Major Alwyn Smith's case bears out not the detail but, I think, the principle of what I put. By transplanting the muscles, it did enable them to carry out the new function which was required of them, which, in this case, was an extremely important one; and I think the further test of the man being able to extend the leg with the full weight of the body on the knee was not required.

LIEUTENANT BILLINGTON (U. S. A.): Very satisfactory progress has been made in operations on the lower extremity, but I think the work of tendon transplantation on the upper extremity has been almost entirely developed since the war began, and we are very interested to see the results, and to know that other men are getting satisfactory results, which encourage us to go ahead in this matter.

There is one tendon transplantation, but somewhat outside the strict subject of this discussion, which is not often needed for gunshot injuries, but which might, perhaps, be discussed for a moment in this connection, and that is transplantation of the extensor proprius hallucis into the metatarsal. This operation was frequently done for infantile paralysis before the war, and there have been very satisfactory results, except for one fact that I observed in cases of my own, and that was a dropping of the great toe, and flexion of the interphalangeal joint, which made it difficult for the child, in those cases, to get a boot on the foot. Oftentimes, therefore, these patients develop corns and ordinary hammer-toe. To obviate that, I have used this technique: Split the extensor proprius hallucis into thirds, an inner one-third portion, and an outer one-third portion divided completely as far down as is needed to go on the toe, and use these two-thirds to pass through the drill-holes in the distal portion of the shaft and first metatarsal, being particularly careful while doing that to hold the toe in a straight line, taking up all the slack in the transplanted two-thirds, so that the toe will not be held in a cocked-up position, so that it can go down to the straight position, and will not cock up or drop further. That obviates a troublesome and oftentimes uncomfortable complication in the cases I have mentioned.

MR. BENNETT: I used to transplant tendons to a great extent in early days. The question of transplantation for deltoid paralysis interests me very much. At one time, cases of Erb's paralysis, or of "obstetric paralysis," which we see so often, did badly until we had General Sir Robert Jones' idea of keeping them well up. But there were cases which did not react, and in those I have transplanted the whole pectoralis major by practically taking it from its insertion into the clavicle and acromion, and dissecting away the deltoid from opposite to it, severing it from the bone. I have seen two cases in which excellent results were obtained in that way. I do not say they were perfect results, but very fair ones for such an operation. In such cases as those, I do not think arthrodesis would have secured such good results as I got from transplantation.

I have been very interested and pleased with Major McMurray's opening contribution. There are certain points in it which struck me a great deal. One point I do not think he dealt with, and that is the terminal phalanges of the thumb. I am myself the object of such an accident. I have no extensor primi, but I have a secundi which does all my work.

In all my cases of tendon transplantation I make a point of using the secundi, because it acts on every joint. I do not agree with Major McMurray in that he says he does not trouble about the secundi pollicis. Beyond that, I think his paper is all that one could desire, and there are certain points which I thank him very much for.

With regard to the question of the anterior crural nerve, my experience of transplantation for anterior crural paralysis is not very great. I do not think I have ever seen, in such cases, anything like a perfect result, such as Major Elmslie would desire. That is so much the case that I have excluded it from

my repertoire of operations to a great extent, and in the cases where I thought it was not possible to do it, I have done an arthrodesis of the joint, and I have carried it out with success. That is to say, I have got a vital, if wooden-like, limb, which is better than a flail and half-useful one.

With regard to fixation of the ankle-joint, I feel that in the majority of cases.—and I am specially thinking of our wounded,—if you have a sutured nerve and there is any chance of action of the muscle, I prefer to let the patient go about with an equinus boot and spring. He then gradually acquires power What, I think, has not been sufficiently appreciated in our hospitals is the question of the relaxation of the extensor muscles. They have loss of tone. and if you relax them, and then gradually get back their tone, you will find, as a result the patient has a useful joint. You get a drop-foot, and that persists during life if you do not get an angular splint on it. It will relapse. But if you have a proper splint on it, it will regain a lot of power. I think if we insist on that we shall be able to save a lot of tendon transplantation, though I agree that in some cases you must have some new elements to help those actions.

With regard to the transplantation of the peroneus brevis, I generally use that muscle, but not by boring through the tibia. I always aim at simplicity in my operations, because I think it is the apex of our art. I never make a second operation if I can help it. If I can, I run the tendon underneath the annular ligament, and round the front. I avoid anything which complicates the operation. So far, I have seen very fair results from transferring it beneath the annular ligament. I know it is difficult, but those cases do well.

MR. MCCRAE AITKEN: I do not think there is anything to add to what has been said, except on one point, and that is, to ask whether Mr. McMurray meant two inches above the ankle for the hole for tendon fixation in drop-foot, and not, as I think he meant, two inches above the ligament. I think he will probably agree with me.

I am glad so many people have referred to the question of the abduction and full extension of the thumb. There is great difficulty in getting a useful hand, and scars round the wrist come into the same consideration. One is doing plastic operations often, in order to get a full grip, especially if the patient is a working man. One case I had was in the person of a bricklayer. and I had to get an apparatus for him to enable him to lay bricks.

I have followed Major Elmslie's advice, and especially in a case in which only the thumb was paralyzed. I got a strong muscle, and he had an extraordinarily strong palmaris.

MR. LAMING EVANS: There is one point of principle which I am not certain has yet been introduced. If so, I missed it. It is ablation of the function of an over-acting muscle. That question entered very largely into transplantation done for infantile paralysis: I have had very little experience of transplantation for gunshot wounds. In infantile paralysis there was one peculiar deformity, where ablation of the function of a muscle and its transference to the other side was of benefit. That was in infantile talipes valgus, where the outer portion of the sole is drawn up, with or without sinking of the longitudinal arch, but generally having no association with it. In those cases, if the function of the peroneus longus is ablated and it is transferred to the other side of the foot and fixed into the tubercle of the scaphoid the result is good. It is an operation which I have done twenty or thirty times. I have watched my cases, and I am convinced that after that there is very great benefit in that particular deformity. I am inclined to think that in such case it is more by the ablation of function than by the introduction of a tendon on the other side. which does not give the patient much muscle power, but often acts as an extra-articular ligament. The function of the foot is invariably improved in that way.

MR. WHITE: This discussion has been, largely, one of technique and end-results. We have not heard much of indications for the operations. There is no question about whether an operation should be done when a muscle supplied by a nerve has been cut away, as well as the nerve itself, and where the question of a primary operation on the nerve is hopeless. And we have not had

any discussion on the question how long after a nerve suture has been done and there is no return of function the case can be adjudged a failure, nor what should be regarded as the time for different nerves. We have first to decide whether an operation should be done, not how it is to be carried out. The same in regard to arthrodesis for the external popliteal, is it necessary, or is it advisable, to do arthrodesis?

MAJOR MCMURRAY (in reply): I thank you very much for your remarks, and for the kindly way in which my paper was taken.

With regard to the loss of sensation following in these cases, we cannot get over the possibility. You can restore motion, you can restore half the function of the hand, but the loss of sensation is a permanent result. Physiologists deny that there is any ingrowing from the cutaneous branches, and we have not seen any yet. In reply to Mr. Girdlestone, it would be useless to try to transplant a tendon to act on a stiff joint; you cannot keep up your treatment of stiffness until after tendon transplantation; it must be mobile and smooth before you do anything.

With regard to the terminal digit of the thumb, I had a hint about that. I have explained that a man can extend the terminal digit of his paralyzed thumb without any transplantation. I have seen 500 cases of nerve paralysis, and of those, 200 have been of the musculo-spiral nerve. I have watched them, and they are able to extend their thumb. Gentlemen in this room have seen cases in which the thumb could be extended three weeks after suture, and recovery was adjudged to be taking place, and I have shown three cases in which no operation had been done, and they also could do it. A man abducts his finger and brings it to the thumb, and he can extend the top of his thumb.

With regard to Major Elmslie's remarks, in which he said you do not need extension of the wrist, you may not, but I think it is of the greatest advantage in the world to have it. The extension is only a passive thing, and it does not give the same amount of "strike" and usefulness and the same fine movements of the fingers as a man gets when he can extend accurately. With regard to posterior interosseous paralysis, I am sorry I did not mention that. My notes were lost, and I forgot about it. I agree that once you have interosseous paralysis you never have a case without scar tissue on the extensor aspect of the forearm. We know that after nerve suture the prognosis is good if you get rid of the scar tissue. End-to-end suture of a nerve in the middle of its course gives a hopeful outlook. If you do the suture at a point at which branches come out, you double the amount of scar tissue for each branch, hence you have four or five times the scar tissue at the junction that you have in the middle of the nerve. That is the reason why the posterior interosseous, where it gives off branches, will not do well with nerve suture.

I agree with Mr. Aitken, I did not mean two inches above the ligament. With regard to Mr. Alwyn Smith's remarks, there is only one reason why it is a useless hand, and that is the stiffness. If it is a mobile hand, with mobile fingers, it is useful. You never have a useless hand with ulnar paralysis. The little finger is weak, but he can move every finger.

With regard to Mr. Bennett's remarks, I do not agree with what he says on the question of arthrodesis. We are going back many years when we talk about arthrodesis, as compared with transplantation. Major Elmslie has probably seen many of these cases. We have ten or twelve of these cases which, before, could not walk at all, but are now, after tendon transplantation, walking up and down the ward: we transplanted the biceps and the semi-tendinosus. The mere fact of being able to go upstairs does not matter, it is an academic point, it does not really make any difference. We have given, by the operation, a stable knee, whereas previously the patient had not such.

Several people spoke about cases in which recovery might be hoped for without tendon transplantation, such as after the use of a splint. No one would think of doing tendon transplantation before those means had been tried: we do not think of doing it until we are certain there is absolutely no chance or possibility of recovery. That is fundamental: there must be no talk of tendon transplantation for the mere sake of getting a particular result.

THE BRISTOW COIL AND THE TREATMENT BY GRADUATED MUSCLE CONTRACTION.

BY ALBERT H. FREIBERG, M.D., CINCINNATI, OHIO.

It is the object of this paper to attract attention to a method of physical therapy which is as yet but little known in this country and which comes from the war practice of our English allies with the assurance of a considerable usefulness. In view of the great tasks of physical reconstruction which are presently to be brought to us as the result of the war in which we are engaged, we must welcome every real addition to our resources. I have undertaken to present a short account of this method for the reason that I have had the opportunity to submit it to a quite thorough practical test with the result of corroborating the merits which have been attributed to it. I have nothing to contribute which is original; neither shall I endeavor to give an extended description of the method since this is readily accessible in the book by Mr. W. Rowley Bristow on "The Treatment of Joint and Muscle Injuries." At the same time it is necessary, in order to make myself understood, that I should make a brief statement with regard to it.

It will not be needful, at this time, that I should discuss the advantage of caring for the condition of the controlling musculature after joint injury since this is generally conceded. The use of massage and of carefully controlled active movements against resistance have become common for this purpose and it is now generally acknowledged that they are of great value. At the same time, we realize that truly efficient massage is by no means always to be had, that its results in the severer forms of joint injury are often slowly attained and that the dosage is not only most indefinite but also entirely dependent upon the personality of the massage assistant. It is not to be understood, however, that this method is intended to supplant the older ones; they are to be used in conjunction.

The fundamental idea of this method lies in our ability to stimulate the damaged muscles to contraction by an induced current in such a way that this may be exactly graduated both as regards degree and rhythm; we may thus begin with contraction of minimal intensity and very slow rhythm and proceed to increase in both regards according to the functional response which is thereby obtained. We have also the very great advantage of being able to limit our stimulation very nearly to a particular muscle or group of muscles and to an

extent not possible with the older methods. The current which is yielded by the Bristow coil differs from that of the usual faradic coil only in so far as it may be used in very great intensity without producing pain and, as before remarked, with the opportunity of quite definitely regulating and graduating the dosage from treatment to treatment and from case to case, as well. No effect is attributed to the electricity as such, except as it is used as the means by which the muscle is made to contract to the desirable degree and frequency. Whether the muscular contraction which is produced in this manner is closely related to the normal physiological contraction in the local metabolic changes resulting therefrom and upon which we depend for definite improvement in strength may be open to question; that the effect is identical can scarcely be claimed. At the same time, the true measure of usefulness of such contractions is to be found in the improvement in both the strength and volume of the muscles. Measured by this standard, my trial of this method appears to have demonstrated definitely the justice of Bristow's contentions and it has, to my mind, established a fixed place for it in the treatment of many joint and muscle injuries and of certain paralytic conditions, as well.

For a description of the apparatus and the manner of its use I shall refer to Bristow's book. It is worth while saying, however, that although it was impossible to procure the apparatus in this country, for a time, it is now being made here in acceptable form and that it is likely to be considerably improved with respect to the mechanism for regulating the current. Although it has not yet been possible for me to observe the effect of the method in a very large series of cases, the cases have been selected with care. After a short period of personal experiment with the coil I turned its use over to a trained masseuse by whom all of the subsequent work was done, under supervision. Bristow's directions have been followed with fidelity and without modification except as we have experimented with active electrodes of different shapes; thus we have found it advantageous to use a longer and narrower electrode for picking out individual muscles in the forearm and leg. It is quite surprising to find to what extent and with what accuracy this may be done. I shall cite a case for the sake of illustration. A woman had sustained a spiral fracture of the proximal phalanx of the ring finger, three years ago; the proximal interphalangeal joint was entirely stiff. The x-ray showed that flexion was blocked by the forward projection of the proximal fragment. This being chiselled away, it was possible to completely flex the joint. After considerable treatment by massage and movements, the patient was

still unable to produce active flexion. With the coil it was possible to produce isolated flexion of the ring finger and treatment by this means very soon resulted in a gratifying restoration of motion. It was quite remarkable that the motion produced by this current was painless at a time when passive motion to the same extent could scarcely be endured.

It would be profitless to report in detail the cases in which this method has been used; it has been tried, however, in all the various types of cases for which Bristow has recommended it, with the exception of traumatisms of peripheral nerves. On the other hand we have used it in some cases of poliomyelitic paralysis in older children and apparently with marked benefit. As a result of this experience, I feel justified in saying that the method may be confidently looked to as a valuable addition to our methods of physical therapy and that we should prepare to make free use of it in the work of military reconstruction. In doing so, however, it is by all means desirable to become thoroughly familiar with the technique beforehand and to adhere closely to Bristow's injunctions. If used carelessly it is possible to cause pain and great discomfort with the current. If properly and carefully applied, on the other hand, it is striking to observe how the quadriceps may be made to extend the knee with great force and without any pain whatever. This may indeed be looked upon as a real test of its value. While it is not offered as a substitute for efficient massage and certainly not to its exclusion when it may be had, the method of treatment by graduated muscle contraction will often be available when truly good massage is not and especially so in military practice.

My experience with the Bristow coil and the method of treatment by graduated muscle contraction has been entirely in private practice and therefore under conditions very different from those of military reconstruction work. It has already been remarked that this experience has been in accord with Bristow's; this may be said without reservation, as far as the fundamental statements are concerned. In some respects, however, it seems worth while to add a few words of comment as the expression of a purely personal experience. While the treatment should be entirely painless if the current be properly managed, it can by no means be denied that the effect of stronger currents is unpleasant. If the muscle be very strongly contracted, the contraction may be painful even though the local effect of the current is not. This may be easily ascertained by experiment on one's own forearm. It is not surprising, therefore, that the treatment is

not well borne by young children and nervous adults. This does not mean that it is not to be used in them, but that more than usual care must be taken in the first few sittings and the graduation must be very slow, indeed. In most patients it is very easy to overtire the muscles—ten contractions should be the maximum, at first. The core should not be pushed entirely in, when beginning, but worked farther and farther in each time. It is most important to heed the injunction to so arrange the position of the limb that complete relaxation is secured of the muscles which are to be treated. It is rarely, if ever, necessary to use the whole strength of the coil.

I have long before now given expression to the opinion that the atrophy of muscle which is so commonly observed in connection with joint injury and disease is not to be adequately explained by the theory of disuse; with this Bristow is in accord. If complete recovery from joint injury is not to be assumed until the controlling musculature has been brought to its primary strength again, then, on the other hand it must also be assumed that, in the presence of a joint lesion which is still active or even progressive by reason of an infectious character, it will not be possible to restore muscular strength by electric or other stimulation; on the contrary, under such circumstances it should be abstained from altogether so long as such conditions are in evidence. This injunction is of added force in view of the fact that in joints the elements of trauma and infection are often found in combination and, what is more important, that the recognition and determination of the infectious element are under such circumstances frequently far from easy. This is said, therefore, by way of caution; should the infectious agent be still in operation, muscle stimulation can do naught but harm. This method is to be used not as routine for every joint injury, but rather as the result of deliberate individualization; employed in this manner it will prove to be of great value.

SEVERE ACUTE SPRAINS OF THE KNEE JOINT.

BY MAJOR MAYNARD C. HARDING, M.C.,

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DURING the first eleven months of 1918 we have treated at Camp Lewis Base Hospital, seventy cases of severe acute sprain of the knee joint. All but six or eight of these cases have been treated in one of the orthopedic wards, and all but that number under my supervision. Acknowledgment is herewith made of the excellent work of all the ward surgeons associated with me in this study.

In view of the importance of diagnosis, some statement should be made of what is and what is not included in this series. It does *not* include the following: Twenty cases admitted as sprain which cleared up under rest and hot applications, returning to duty in one week; twelve cases of abrasions and wounds in the region of the knee in which the joint damage was indefinite; five cases of synovitis following a hike, without definite history of a trauma. These cleared up rapidly—three of them after aspirating a large amount of clear synovia. Ten cases of acute semi-lunar displacement—all recurrent and not accompanied by other signs of sprain. A large number of cases of chronic hypertrophied fringes and thickened alar bursae resulting from previous trauma, which had been lighted up by accident or strenuous work. These latter are a problem within themselves, and not less than one hundred have passed through the orthopedic clinic.

In the cases here reported all the classical symptoms and signs of sprain were present in every patient: History of accident, immediate disability, usually total, pain, prompt swelling, effusion, and tenderness over the torn capsule. As stated, they number seventy, the majority of which have been discharged, while those remaining in hospital are far enough advanced to warrant an accurate prognosis.

After comparing notes with surgeons from a number of camps, I am convinced that this type of injury is rather more common here than elsewhere. This applies equally to fractures of the ankle joint, of which we have had some sixty to date. The reasons seem to be two: First we have a longer wet season than any other camp. Second, our terrain is everywhere composed of smooth round rocks from the size of a marble to big cobbles, loosely imbedded in a porous soil. In the wet season they are slippery; in the dry they roll, affording the runner and jumper poor footing. It is significant that the majority of these sprains and ankle fractures were acquired either while running or jumping.

As to location of the sprain, they are classified as follows:

General sprain, forty per cent.
Internal lateral ligament, forty-two per cent.
Internal semi-lunar cartilage, thirty-one per cent.
External lateral ligament, one case.
Periosteal tear internal condyle of femur, two cases.
Cracks of patella, three cases.

It will be noted that some patients present more than one diagnosis—internal lateral ligament and internal semi-lunar cartilage being the common combination. Twenty per cent. gave a history of previous similar injury.

All had effusion. Sixty-five per cent. were aspirated, six per cent. being aspirated twice. Of the forty-six cases thus aspirated, eighty-seven per cent. had bloody fluid, ranging from blood stained synovia to blood so pure it partially clotted on exposure to the air. Thirteen per cent. had clear fluids, half of which were obtained on first aspiration, and half on second, following a bloody fluid. The amount varied from 30 c.c. to 120 c.c., the average being 63 c.c. All fluids were examined by smear and culture. While the smear showed an occasional organism, the cultures were invariably negative with the exception of one, which showed a growth of gram negative diplococci. Since that knee gave no signs whatever of an infection, behaving exactly like the others, it is fair to presume that this was an accidental contamination.

The x-ray findings, naturally, were mainly negative, though some interesting and valuable positive findings were reported. Three crack fractures of the patella were noted. Three old dislocated semi-lunar cartilages were diagnosed and later verified by operation. Thickened and slightly calcified alar bursae were noted in a few cases. Two cases presented periosteal tears of the internal lateral ligament from the femoral condyle.

It is seldom that the pathology of the capsular and synovial injury is examined by the eye and touch in this type of injury. Four of this series came to operation—two for torn semi-lunars on the sixteenth day; one for repair of the capsule on the tenth day; one for a congenital hernia of the capsule on the thirty-fifth day. To these may be added one case operated at the Letterman General Hospital on the tenth day. The damage to the capsule ranges from stretching, which is the condition common to all grades, up to the completest and most bizarre tears running almost one-third of the way around the joint. The stretching is accompanied in all but the mildest types by tearing

of individual fibres of the white tissue, just as in other localities. To the original trauma must be added the stretching of the capsule by the effusion, which, in my opinion, is a prominent cause of disability and slow recovery. The synovial membrane is apt to be torn at the same region as the capsule. The entire inside of the knee joint at the tenth or sixteenth day looks as if lined with wine-colored velvet. The venous engorgement is so pronounced, and the swelling of the synovial membrane is so marked that one is struck forcibly by the intensity of the reaction going on. After viewing it, one is dense, indeed, if he persists in ordering early motion and weight bearing. The alar bursa is thickened and partakes in the reaction. Its swelling brings it often well between the bones and makes it more liable to be pinched.

The crucial ligaments are rarely involved, only one case showing such damage. The reason lies in the mechanism of the trauma. It is a flexion injury. At the instant of the sprain the knee is usually slightly crooked. It at once bends and the patient falls to the ground, or into some position where the tension on the crucial ligaments is relaxed. In those cases where the straight knee receives a blow from one side, and cannot crumple, crucial damage may be expected. Such was the condition in our one case, which was accompanied by extensive tearing of the capsule.

Profiting by the observations of a large number of similar cases, an effort was early made to standardize the treatment along certain broad lines, according to the pathology of the injury and the mechanism of repair. As soon as the case has been examined a light board splint is placed under the leg, if handling is painful. A tentative diagnosis is made and an x-ray secured at once. Upon receipt of the report from this laboratory the knee is aspirated, if enough fluid is present to distend the capsule at all.

The technique of aspiration merits more than a passing mention. Properly done, it is a safe and almost painless procedure. These cases are taken to the clean surgery, and the same rigid antiseptic technique as for a major operation is observed. No local anesthetic is used unless the patient is very nervous. He is cautioned not to bend his knee lest he break the needle off inside. A moderately course needle attached to a Luer glass syringe is used. Locate the outer edge of the patella one finger breadth below its upper end. Point the needle inward at right angle to the leg and tilt it backward enough to clip under the edge of the patella. If the patella is struck, the needle may slip in front. If pointed too far back the mesial edge of the condyle will

be struck and severe pain caused. Carry the needle in about two inches by a steady thrust, then gently draw on the piston. If no fluid comes, push in until the bone is reached, which will be at a depth of about two and one-half inches. The tip of the needle now lies in the hollow between the condyles under the center of the patella. At this spot redundant folds of synovial membrane are not apt to block the needle. At any other point in the knee joint this will almost invariably take place, causing great annoyance and even preventing aspiration. Part of the first syringeful is squirted into a sterile culture tube and sent to the laboratory. When no more fluid comes, the assistant grasps the front of the leg above and below the joint, encircling as much of the limb as possible. The hands are slid together, milking the contents of the joint toward the needle, when more fluid can usually be drawn. The puncture wound is sealed with collodion.

A cotton compression bandage is applied and if much pain is present, or any semi-lunar involvement, a posterior moulded splint is added. Forty-five of our cases required both. The patient is returned to bed, where he is kept so long as swelling and fluid persist. This is rarely over three days. He is then allowed up on crutches, but not allowed to touch the foot to the floor. In a few days, if no swelling or pain recurs, he is allowed to bear a little weight, still using his crutch. This will average about the ninth or tenth day. If at any time swelling recurs, he is put to bed until it subsides. This is of the utmost importance, and if neglected will lead to the formation of an indurated, boggy joint that is slow to resolve.

The duration of pain with the patient at rest and dressing applied showed an interesting difference, according to treatment. The aspirated cases had pain for an average of one and one-half days, while the unaspirated cases, with all equal distention, averaged eleven days. From the first, these joints are baked with a small portable electric baker. During the baking the patients gently rub their knees and legs. As soon as soreness is gone more forcible massage is given, and the baking extended to an hour daily. The posterior splint is removed as soon as pain and soreness leave; within a few days at most. Two five-yard flannel rollers are then given the patient and he is instructed in putting on a figure-of-eight bandage. This he wears constantly for about three weeks, when he takes it off at night. The man takes his bandages with him from the hospital and is ordered to wear them at least three months. Before being sent from the hospital he is taken for several hikes, reporting for examination on his return. The last

one is at least five miles, and he is not discharged unless he can stand this without reaction.

Cases showing semi-lunar symptoms are kept on a posterior splint four weeks. If they are to be operated it should be done after the symptoms of sprain have subsided. The two cases done on the sixteenth day did well, but I believe there was still too much reaction present. The last one opened in the fifth week has done better. The results of the treatment have been, on the whole, satisfactory. The average stay in the hospital was forty-six days. Eighty-nine per cent. returned to duty. Nine percent. to limited service. Three cases went recently to quarters, the ultimate disposition being doubtful.

On reviewing this series it is perfectly evident to me that these cases can be further subdivided into two classes. One, a general sprain with moderate effusion which may or may not absorb under pressure and rest. You can tell after a week that they will be ready for duty in about thirty days. It is from the uniformly fair results in this type that the "let-alone" policy of treatment has become popular. The other type may look the same, but the fluid is very bloody and tends to recur promptly. Definite capsular tears can be made out. They are usually of the internal lateral ligament, being quite often associated with internal meniscus displacement, or even bony injury. These cases, treated by the "let-alone" method, or the more harmful one of forced motion and early weight bearing, result in chronically weak knees. They react badly to every strain or trauma in after life, forming the bulk of the scores of chronic knees showing up in the orthopedic clinic. They need all the care here outlined, and often more, while from two to four months are required to return them to duty. Since twenty per cent. of these cases give a history of previous injury, it is fair to suppose that many of them will again break down, this being especially true of the severe type last mentioned.

CONCLUSIONS.

From a study of this series a few important lessons can be drawn.

First, careful diagnosis of the type of sprain.

Second, aspiration of any distended joint promptly, since practically all effusions are bloody and absorb slowly. I have found them present after many weeks and they lead to the formation of a thickened, chronic joint.

Third, prevent distention of the capsule, as it is one of the main causes of a weakened knee in after life.

Fourth, early baking and massage.

Fifth, strict supervision of the manner of returning to use.

SOME PRACTICAL APPLICATIONS OF PATHOLOGY TO THE WAR INJURIES OF NERVES.

BY SYDNEY M. CONE, CAPTAIN, M.R.C., U.S.A.

[From the Alder Hey Military Orthopaedic Hospital and the Thompson Yates Pathological Laboratory, University of Liverpool.]

INTRODUCTION.*

THE Microscopic Appearance of War Injured Nerves was described by me recently in *The British Journal of Surgery*, Vol. V, No. 20, and the *Journal of Pathology and Bacteriology*, Vol. XXII. Now we will deal with the macroscopic findings. For this work I have more than four hundred specimens, gathered during the last year while working at the Alder Hey Military Orthopaedic Hospital.

The material was examined at the operating table, and described at once, using the knowledge gained by the microscope to interpret the changes seen in the injured nerves.

The neurokeratin stain enabled me to settle at once any doubt as to the character of tissues described. One can, by free hand or frozen sections, make a satisfactory microscopic report on nerve specimens within ten minutes.

MACROSCOPIC EXAMINATION OF TISSUES.

In examining tissues one must note systematically: size, shape, location, color, circumscription or infiltration, consistency, translucency and homogeneity.

Protoplasm (cells) *en masse* is translucent (gelatinous) gray, more or less edematous and bulging; where it is compact the appearance is gray and opaque, fat is yellow, muscle red, arterial circulation pink, venous congestion blue, and broken-down blood brown. Fibrous tissue is hard to tear, grates on cutting, and may only be separated readily from surroundings when circumscribed or when it has reached its full growth and is beginning to contract. It cups on section when dense, and retracts about softer more cellular material.

NORMAL NERVE.

A normal nerve appears very much like tendon, but is not so compact or glistening. It is milky white and when flattened, individual pearly white lines may be seen on a translucent pink or bluish background (depending on the circulation). It may be readily teased—the individual bundles being held together by a very fine reticulum of connective tissue.

* Figures referred to are in the *British Journal of Surgery*, Vol. v, No. 20.

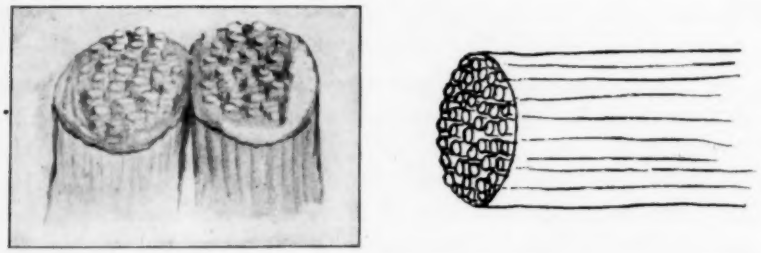

FIG. 1.—Nerve trunk. Bundles appear normal. Excess of connective tissue.

Cross section demonstrates numerous half millimeter-sized points in a pink translucent background. On pressure these protrude like pistils of a flower. One may be readily extracted from its bed.

The connective tissue about these bundles is continuous from sheath to the finest bundle (fasciculus) and carries a very excellent blood supply—large vessels being found under the sheath and at the center.

Smaller anastomosing vessels course alongside the inner fasciculi sending capillaries into them.

The pink or bluish color of the stroma depends on the preponderance of arterial or venous blood.

In pathological nerve tissue the appearance varies from the normal because of proliferation of nerves, connective tissue and blood vessels (which are enormously increased) and the presence of blood pigment, fat or muscle.

We must understand the tissues at the seat of injury, as well as the nerve trunk. The proper interpretation of the gross appearance of the material away from the mass of scar ("chelicide nerveuse" of Dejerine) will often save the surgeon much difficulty and the patient months of time in recovery. This knowledge of the macroscopic anatomy will give confidence to the operator in a position where he is often in doubt as to the kind of tissue he is cutting. There should be no question as to the fact that whatever he does to remove the dense compressing tissue is well done, for the nerve will do the rest whether sutured or merely freed. Many cases which appear to require suture, because of the firmness of the nerve or the conglomerate mass at the seat of dissection, would recover sooner if the surgeon desisted as soon as he recognized "nerve callus" connecting the two nerve trunks. Our earliest recoveries are cases in which the sutured ends were "nerve callus." Moreover, my guinea pig experiments demonstrate this material most active when transplanted. After division the nerve regenerates rapidly at both ends—the central end reaches maturity at

once, the peripheral end forms immature nerves by a multiplication of the sheath of Schwann cells (neuroblasts). These embryonal nerves mature very often through unexpected central connections picked up in one or more of four methods. (See Cone, *British Journal of Surg.* Vol. V, No. XX, 1918, p. 537).

The work done in the laboratory to confirm the gross descriptions and interpretations was done by a method (neurokeratin stain) described in this journal.

NERVE BULBS.

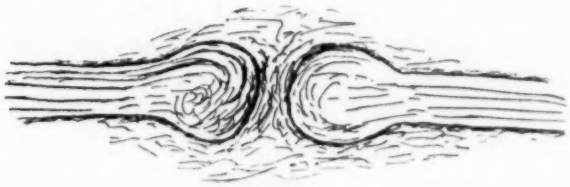

FIG. 2.

FIG. 3.

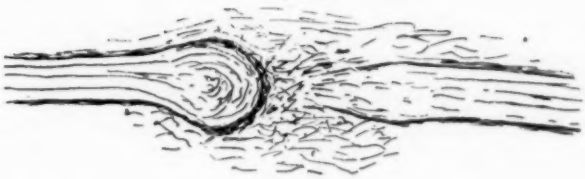

FIG. 4.

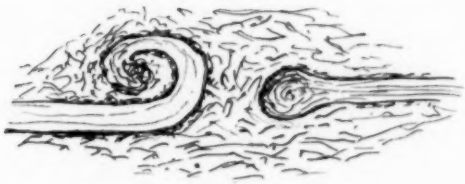

FIG. 5.

FIG. 6.

The nerve bulbs ("nerve callus" masses), whether seen as end bulbs, side bulbs or at the ends of nerves in amputation stumps are always circumscribed, rounded, hard, grayish white masses, resembling compressed fibrous tissue. There is a grating on section and one sees on close inspection (especially on pressure) innumerable fine gray translucent dots. Sometimes there are larger gray or grayish pink translucent areas in these "nerve callus" masses.

The gray color is due to bundles of young 1-3 sized, much nucleated nerve tendrills in a stroma of fine connective tissue (Figs. 430, 433). The translucent dots are cross sections of the very small bundles (fasciculi). Each fasiculus contains ten to forty tendrils (Fig. 413). When the stroma is very cellular and vascular a pink color is added to the gray.

When the bulb is seen in its earliest more cellular, nucleated stage of growth, translucent grayish pink, succulent, bulging, pinhead areas present themselves among the grayish pink lines. Not infrequently the nerve trunk fibres may be traced into the bulb entering at the side or center and spreading. These are milk white lines in a pink stroma which are gradually lost in the homogeneous gray of the bulb.

The symmetrical elliptical bulb seen in the continuity of an injured nerve, often contains pieces of shrapnel. This is succulent (oedematous) grayish pink with milk white lines traversing it. Sometimes they are gray and firmer. Whatever else may be present in the nature of inflammatory exudate, progressive tissue change, and foreign bodies, young nerve proliferation is always found.

This growth is not so wild nor so abundant as in the "nerve callus" of bulbs just described. The latter is the same kind of formation in a non-oedematous tissue. The firmer gray ones contain more of the interlacing young nerves in fasciculi, characteristic of "nerve callus." They are sometimes discolored brown by granular blood pigment. This tissue should not be excised—it offers an excellent medium for nerve growth and contains many continuous good adult fibres. Longitudinal incision (hersage) may be practised but it has been found that neurolysis (relieving adhesions) alone produces satisfactory results.

A nerve badly torn for part of its extent, does not always bulb. In dissecting scar from about an irregularly torn nerve one comes upon gray and white lines leading to minute globular, translucent, pinkish gray tissue resembling lymphoid follicles. These vary in size from 1 to 3 mm. and are continuous with fine gray to milk white lines of the nerve trunk.

FIG. 7.

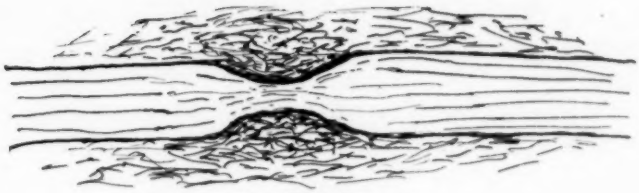

FIG. 8.

FIG. 9.

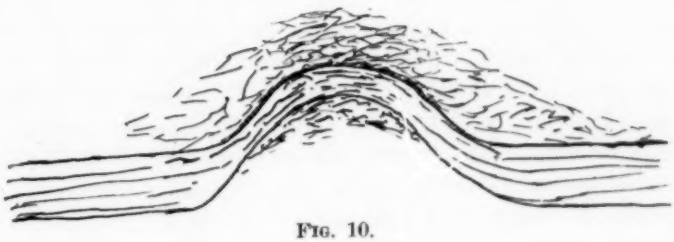

FIG. 10.

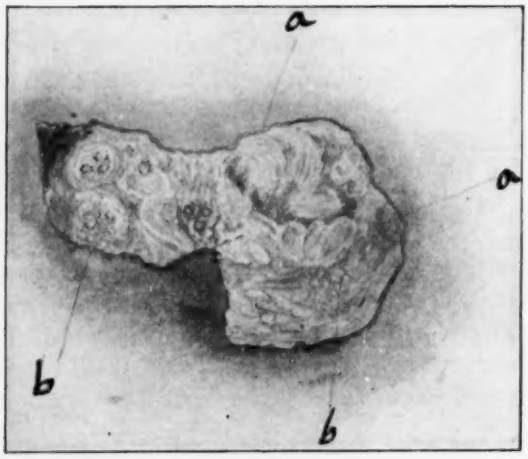

FIG. 11.—(*a*) Nerve callus; (*b*) Young nerve in bundles.

FIG. 33.

The microscope demonstrates these bodies to be miniature nerve bulbs of a very young cellular nerve type like Fig. 429; the gray lines are fasciculi of nerve tendrils (Fig. 432); the white lines are adult nerve fibres (Fig. 407). This nerve is regenerating unevenly—its smallest funiculi being torn at different levels. The tissue should not be excised for it is young proliferating nerve and offers an excellent medium for nerve growth. There are many adult uninjured fibres among the young ones. Removal of the scar and formation of a good occlusive muscles fascia bed should suffice.

NERVE COMPRESSED IN SCAR.

There are several types of contracted nerves due entirely to scar: one, compressed for a larger area; another, constricted for a very small extent. And, again, where with the constriction the nerve is diverted from its course. These nerves appear gray in color, are firm and may be rough or smooth.

Gross section is homogeneous and gray. Sometimes there are translucent gray or grayish pink dots indicating the presence of proliferating nerves,—this is rare. As a rule, the tissue is vascular and fibrous.

In one case out of more than four hundred the nerve, although constricted by a dense sclerotic band for one half an inch, showed on cross section bundles of milk white nerve fibres, protruding like pistils of a flower. There was no new formation of connective tissue within the sheath and the nerve fibres did not take the "neurokeratin" stain. Many showed balls of myelin (Wallerian degeneration). In this case relief of th constricting band would have been sufficient.

In the more common old densely constricted nerves, excision is required, for no adult fibres and few young ones are seen. If, however, on making a longitudinal incision, translucent gray areas or lines are seen in large numbers, relief from the surrounding scar is all that need be done. These areas are healthy young nerves and play the most active part in repair.

Nerves pulled from their path by scar or bone callus are narrowed and functionless. Function returns on relieving tension and freeing from scar.

One such nerve which has been slightly torn was examined. It showed both normal adult fibres and actively growing young nerves.

"NERVE CALLUS" IN ADHESIONS.

The gray firm tissue about war injured nerves, is commonly thought to be altogether scar tissue. I have shown in previous writings that adhesions about nerves contain nerve callus in 82% of cases. Now I can place the percentage higher.

Close observation will show translucent areas of grayish pink or gray, more or less circumscribed and easier to separate from their surroundings than scar. These masses are "nerve callus" (Fig. 431). They are invariably found close to nerve tears, around bulbs and I have found them around the seat of old nerve suture cases. *Finding "nerve callus" look for nerve injury.*

In one case such material in a skin scar led to an unexpected injury of the median nerve. In other cases, following this "nerve callus" has been of value in finding the nerve lesion.

In many instances it is formed from nerves to surrounding vessels, skin and muscle. This material may subserve a useful function in causing the otherwise embryonal nerve of the distal severed end to reach maturity. A central connection is made by these surrounding young nerves.

CHRONIC NEURITIS.

Nerves may be indurated, swollen, gray and homogeneous and yet show linear white markings when the seat of chronic inflammation (some observers refer to the changes about these infected war injured nerves as chronic neuritis). The cellular infiltration and connective tissue increase cannot be distinguished from the same in war injured nerves, any more than in any other clean cut or infected wound, where we no longer use terms like dermatitis and myositis. When these changes pass beyond the precincts of the injury and involve the nerve trunk some distance away, we may look on the condition as a secondary nerve involvement.

HYPERPLASTIC NEURITIS.*

With the cellular infiltration and connective tissue formation along the nerve trunk, I have noted in very many instances a great hyperplasia of young varicose nerve tendrils, winding about the normal nerve fibres in a very vascular loose connective tissue matrix. This cannot be distinguished by the naked eye from any other forms of nerve infiltration. Clinically, however, I take it to mean much. There is an intractable painful consalgia of war injured nerves for which even excision has been found insufficient in relieving, and for which Sicard has used alcohol injections with splendid success. I think this form of neuritis is due to the wild growth of young nerves among the old nerve fibres. The term "hyperplastic neuritis" might be used to indicate this condition.

COMMENTS ON THE PROCEEDING.

I indicated in the introduction that the connective tissue stroma of a normal nerve is easily frayed out and that the nerve bundles are readily pulled from their nests. This becomes increasingly difficult

* Not a most satisfactory term, but distinctive.

as the inflammatory new tissue formation increases and new vessels twine in and out among the old and new nerve fibres and bundles. The sheath and the epi-peri- and endo neurium, are all involved in the proliferation (Fig. 427). We find old blood pigment within phagocytes and free in the tissues. It is strange that we so seldom find small round-cell infiltration and polymorphonuclear leucocytes; they evidently quickly give place to a progressive tissue change.

It is the formation of this young connective tissue which makes so difficult the tearing apart and differentiation of the old injured nerve from the surrounding scar.

The scar is a much more intimate welding and intertwining of fine lines of tissue than is the "nerve callus" mass, and therefore much harder to tease or tear apart. Figure 33 represents this. Here we have the entire exsected piece photographed. The young nerve bundles are seen deeply stained and definitely separated, while the unstained scar is a mass of finely interlacing fibres.

I wish to thank General Sir Robert Jones for the opportunity afforded me to do this work. To Professor Ernest Glynn I am greatly indebted for his continued interest.

THE CHANGES PRODUCED IN THE GROWING BONE AFTER INJURY TO THE EPIPHYSEAL CARTILAGE PLATE.

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[From the Pathological Laboratory and the Surgical Pathological Laboratory of Leland Stanford, Jr., University School of Medicine.]

(*Continued from page 99.*)

Experiment 44. 44 Days. Dog 129-79.

Operation. The lateral one-half of the metacarpal IV of the left fore foot is removed. The length of the bone is 3.0 cm. The animal died at the end of 44 days.

Gross Findings. The healing is good. The exposed lateral half of the bone is almost entirely enclosed by a new osseous cortex. There is no union with the surrounding dense connective tissue. There is a tendency for the bone to assume a round form like normal cortex. There is a definite marrow cavity within the new cortex except in the region of the articular cartilage. The epiphyseal cartilage plate has relatively a normal appearance. The Roentgenogram shows the operated bone with definite effort to assume its original form. There is some shortening and distortion of the epiphyseal end. (See Fig. 5.) The measurements are: Metacarpal IV., left, 3.2 cm.; difference, 0.25 cm.; right, 3.45 cm. Thus there is a loss of 0.25 cm. in growth. The length of the bone has increased 3.2—3.0=0.2 cm., while the normal increase has been 3.45 cm.—3.0 cm.=.45 cm.

FIG. 5.—Experiment 44. 44 days. Dog 129-79. Removal of the lateral one-half of the bone. The second bone from the right, 4, of B, is the operated bone. There is only a small amount of shortening as the normal growth has likewise been small. Notice the tendency of the bone to assume its original form.

Experiment 45. 106 Days. Dog 21-54.

Operation. Removed the medial one-half of the metacarpal IV of the left hind foot. The estimated length of this bone is 3.0 cm. The animal died at the end of 106 days.

Gross Findings. The entire foot appears slightly smaller than normal. There is a small amount of articular cartilage still present. The epiphyseal cartilage plate has disappeared in the operated bone but is still present in the normal. The measurements are: Metatarsal IV. left (op.), 3.2 cm.; difference, 2.3 cm.; right, 5.5 cm. The loss in growth is 2.3 cm. The entire growth since the operation is about 3.2—3.0=0.2 cm., while the normal growth is 2.5 cm.

SUMMARY ON EXCISION OF ONE-HALF OF THE ENTIRE LENGTH OF THE BONE.

There is practically a complete cessation of growth after such an operation. This is due to the combined effect of injury to the epiphyseal cartilage plate and to disturbances of the blood supply both from the epiphyseal and nutrient arteries.

There is a tendency for the reëstablishment of the normal round form of the split half of the bone.

TABLE XII.

EXP. NO.	DOG NO.	DURATION	LOSS OF GROWTH	GROWTH OF OPERATED	GROWTH OF NORMAL
43	150-87	3 days	0	0	0
44	129-79	44 "	0.25 cm.	0.2 cm.	0.45 cm.
45	21-54	106 "	2.3 cm.	0.2 cm.	2.5 cm.

GROUP V. CROSS INCISION WITH REMOVAL OF DISTAL FRAGMENT.

1. Through the Epiphysis.

Method. Made an incision across the epiphysis distal to the epiphyseal cartilage plate and removed the distal piece.

Experiment 46. 1 Day. Dog 27-56.

Operation. Removed the epiphysis of the metacarpal IV. of the right forefoot almost up to the epiphyseal cartilage plate. The piece removed is .4 cm. in length. The part remaining is 2.5 cm. The animal died the next day.

Gross Findings. The time is too short to show any changes in structure.

Experiment 47. 9 Days. Dog 28-73.

Operation. Removed the epiphysis of the metacarpal III. of the left forefoot just distal to the epiphyseal cartilage plate. The length of the remaining piece of bone is 2.6 cm. The animal died at the end of 9 days.

Gross Findings. The wound is clean and there are no visible abnormalities to be found. The measurement of the operated bone is: Metatarsal III., left, 2.6 cm. Thus there is no increase in length.

Microscopical Findings. The specimen shows a thick layer of fibrous tissue over the end of the bone, and a slight tendency of ingrowth of cartilage at the periphery. The remainder of the epiphysis, the epiphyseal cartilage plate, the metaphysis, and the diaphysis appear normal.

Experiment 48. 16 Days. Dog 65-58.

Operation. Removed the portion of the epiphysis of the metatarsal IV. of the right hind foot distal to the epiphyseal cartilage plate. The part remaining measures 2.1 cm. The animal died at the end of 16 days.

Gross Findings. There is good healing. The cut end appears roughened. The measurement of the operated bone is 2.2, showing that no growth has taken place.

Experiment 49. 62 Days. Dog 124-77.

Operation. Removed the greater part of the epiphysis of the metacarpal III. of the left forefoot. The part remaining is 2.4 cm. in length, while the total length is 2.9 cm. The animal died at the end of 62 days.

Gross Findings. The cut end is healed over but there is no new joint cavity. On section there does not appear to be any increase in size of the epiphysis. The epiphyseal cartilage plate appears normal, as does the remainder of the bone. There is a growth of 3.05—2.4=0.65 cm. in the operated bone, while the normal growth is 3.7—2.9=0.8 cm.

Microscopical Findings. The cut end is covered by fibrous tissue which, in places, has a hyaline-like appearance. There is no definite evidence of new articular cartilage. The remainder of the bone, including the marrow and trabeculae of the epiphysis, is normal.

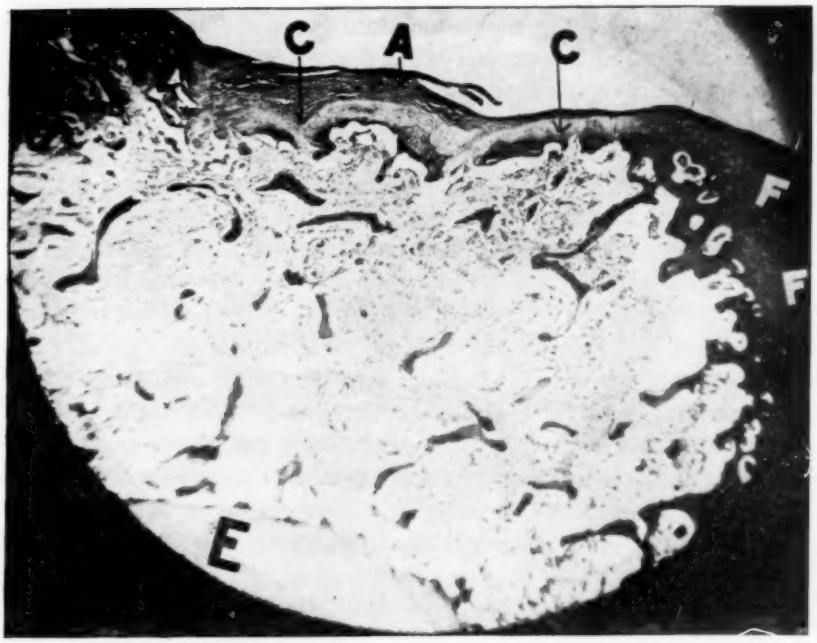

FIG. 6.—Experiment 50. 67 days. Dog 102-69. Cutting across the epiphysis and removing the articular end of the bone. The cut end of the bone is enclosed by new tissue that appears somewhat like an articular surface. On the outside there is a layer of fibrous tissue within which there is a layer of new cartilage. The origin of this new cartilage can not be definitely determined. A portion appears to be extending in from original cartilage that connects the articular cartilage with the epiphyseal cartilage plate, FF. Some of the cartilage is closely connected with the bone trabeculae from which it might take origin. Another source of origin could be from the connective tissue through a process of metaplasia. A, outer layer of fibrous tissue; C,C, inner layer of new cartilage; F,F, original cartilage connecting the articular cartilage with the epiphyseal cartilage plate; E, epiphyseal cartilage plate (just on the edge of the field and out of focus). Microphotograph. Objective 2/3. Ocular 2 inch B. and L

Experiment 50. 67 Days. Dog 102-69.

Operation. Removed the epiphysis distal to the epiphyseal cartilage plate of metacarpal III. of the right forefoot. The total length of the bone is 2.65 cm. The length after removal of the epiphysis is 2.15 cm. The animal died at the end of 67 days.

Gross Findings. There is good healing. The cut end of the bone is rounded off, and appears to be covered with a thin layer of cartilage. The epiphyseal cartilage plate appears normal and bears the

same relative position to the end of the bone that it did at the time of the operation. The remainder of the bone appears normal. The measurements are: Metacarpal III.=3.2 cm.; at the time of operation, 2.15 cm.; amount of growth, 1.05 cm. Metacarpal IV.=3.95 cm.; at time of operation, 2.65 cm.; amount of growth, 1.30 cm. Thus there is almost as much growth in the operated bone as in the normal bone.

Microscopical Findings. The cut end of the bone presents an interesting microscopical picture. Near either border there appears to be a definite ingrowth of cartilage from the remains of portions of the lateral aspect of the articular cartilage. The cut end is surrounded by a dense mass of fibrous tissue; on the inner side of this, near the cut end of the bone, there are areas of young cartilage cells and osteoid tissue. These new masses of cartilage cells and osteoid tissue might be formed by a metaplasia of the fibrous tissue. However, they bear close relationship to the trabeculae of the epiphysis, which seems to be the more likely source of this new tissue. There seems to be a definite attempt to reëstablish a new articular surface (Fig. 6). The remainder of the epiphysis appears normal. The epiphyseal cartilage plate has a fairly normal structure. The metaphysis and diaphysis are normal.

SUMMARY ON REMOVAL OF THE GREATER PART OF THE EPIPHYSIS.

There is practically no disturbance in growth or structure of the epiphyseal cartilage plate.

There appears to be a definite tendency to form a new articular surface of cartilage and osteoid tissue after removal of the entire end of the bone.

TABLE XIII.

EXP. NO.	DOG NO.	DURATION	LOSS OF GROWTH	GROWTH OF OPERATED	GROWTH OF NORMAL
46	27-56	1 day	0	0	0
47	28-73	9 days	0	0	0
48	65-58	16 "	0.2 cm.	0.2 cm.	0.4 cm.
49	124-77	62 "	0.15 cm.	0.64 cm.	0.8 cm.
50	102-67	67 "	0.25 cm.	1.05 cm.	1.3 cm.

2. Removal of the Entire Epiphysis up to the Metaphysis.

Method. After exposing the bone an incision is made through the perichondrium about the epiphyseal cartilage plate and a separation produced in the line of cleavage. The distal epiphyseal fragment containing the epiphyseal cartilage plate is then removed. The wound is closed as usual.

Experiment 51. 9 Days. Dog 29-73.

Operation. Removed the entire epiphysis of the metacarpal IV. of the right forefoot. The total length of the bone is 2.5, the part remaining is 1.9 cm. The animal died at the end of 9 days.

Gross Findings. There is a layer of fibrous tissue enclosing the end of the bone, but no evidence of change in the bone.

Microscopical Findings. There is a thick layer of fibrous tissue surrounding the end of the bone. The thin layer of cartilage that covers the metaphysis is absent, as are the cartilage buds of the metaphysis. The remainder of the bone appears normal.

Experiment 52. 22 Days. Dog 148-86.

Operation. Removed the entire epiphysis after separating in the natural cleavage plane. The total length of the bone is 2.8 cm., while the piece remaining is 2.2 cm. The animal died at the end of 22 days.

Gross Findings. There is good healing. The end of the bone is encapsulated with fibrous tissue. There is very little evidence of bone proliferation except on the plantar surface. The Roentgenogram shows the loss in growth, as is noticed by a comparison of the diaphysis of operated and normal bone. (See Fig. 4.) The measurements are: Metacarpal IV., at autopsy, 2.3 cm.; metacarpal IV., at operation, 2.2 cm.; amount of growth, 0.1 cm. Thus there has been practically no growth since the operation. The normal growth is 3.4—2.8=0.6 cm.

Experiment 53. 62 Days. Cat 59-48.

Operation. Removed the epiphysis of the metatarsal III. of the right hind foot. The part remaining measures 2.2 cm. The animal died at the end of 62 days.

Gross Fidings. There is good healing. There appears to be a slight outgrowth at the end of the bone. The measurements are: Metatarsal III., at autopsy, 2.3 cm.; metatarsal III., at operation, 2.2 cm.; amount of growth, 0.1 cm. Thus there is but 0.1 cm. of growth. The normal growth is at least 1.3 cm.

Microscopical Findings. The end of the bone is encapsulated in fibrous tissue. There is no evidence of metaphyseal cartilage buds, only some heavy osseous trabeculae being present. At one border of the bone there is a proliferation of cartilaginous tissue from the osseous tissue which has taken on an arrangement similar to that of the articular cartilage. The remainder of the bone appears normal.

FIG. 7.—Experiment 54. 68 days. Dog 120-75. Removal of entire epiphysis. The removal of the epiphysis of 3A is complete. There is a marked hindrance in growth that can easily be ascertained by comparing the diaphysis of 3 and 4 of A, which are normally equal. The shadows at the distal ends that might be mistaken for portions of the epiphysis are sesamoid bones. The shaft of the bone is irregular and rarefied.

Experiment 54. 68 Days. Dog 120-75.

Operation. Removed the epiphysis of the metatarsal III. of the right hind foot. The total length of the bone is 3.45 cm. and the portion remaining is 2.75 cm. The animal died in 68 days.

Gross Findings There is good healing. There is practically no evidence of growth. On longitudinal section the cut end is found to be encapsulated by fibrous tissue. There is no evidence of epiphyseal cartilage. The marrow appears normal. The Roentgenogram shows the marked shortening, the slight irregular bone proliferation, and the rarefactions of the shaft. (See Fig. 7.) The measurements are: Metatarsal III., at autopsy, 3.0 cm.; metatarsal III., at operation, 2.75 cm.; amount of growth, 0.25 cm. Thus there has been but 0.25 cm. of growth since the operation. The normal growth has been 4.65—2.75=1.9 cm. So that here has been practically a complete cessation of growth since the operation.

Microscopical Findings. The cut end of the bone is surrounded by dense fibrous tissue. There is still the remnant of metaphyseal cartilage covering the bone end. In some places there are irregular columns of cartilage resembling the epiphyseal cartilage columns. These might be the remains of the original columns. Whatever proliferation has taken place is of a purposeless nature.

Experiment 55. 81 Days. Dog 19-53.

Operation. Removed the epiphysis of the metatarsal IV. of the left hind foot. The length of the bone after removal of this piece is 2.25 cm. The total length of the normal bone is 2.8 cm. The animal was killed by illuminating gas at the end of 81 days.

Gross Findings. There is a sort of new joint composed of fibrous tissue about the cut end, allowing a certain amount of mobility. On longitudinal section the end of the bone is found to be covered by a mass of fibrous tissue 1.5 cm. thick. There is a white band that looks like the remains of the epiphyseal cartilage plate. The remainder of the bone appears normal. The Roentgenogram shows the shortening and lack of proliferation, which can easily be made out by comparing the diaphysis of the operated with the normal bone. The measurements are: Metatarsal IV., at autopsy, 2.85 cm.; metatarsal IV., at operation, 2.25 cm.; increase in length, 0.60 cm. Thus there is an increase of 0.60 cm. in length since the operation. The normal increase is 5.05—2.8=2.25 cm.

Experiment 56. 126 Days. Dog 89-64.

Operation. Removed the epiphysis of the metatarsal III. of the right hind foot. The piece remaining measures 2.0 cm. The animal was killed with chloroform at the end of 126 days.

Gross Findings. There is good healing. The end of the bone is pointed and surrounded by dense fibrous tissue. The Roentgenogram shows the entire distal end of the bone narrower than normal. The cut surface is irregular. The diaphysis of metatarsal III. is shorter than the diaphysis of metatarsal II., whereas normally it is much longer. (See Fig. 8.) The measurements are as follows: Right metatarsal III., at autopsy, 2.9 cm.; right metatarsal III., at operation, 2.0 cm.; increase in length, 0.9 cm. Thus there is an increase of 0.9 cm. in the length of the operated bone. This is irregular and pointed, like an outgrowth of bone along a strip of periosteum. The normal growth during this time was over 2.0 cm.

FIG. 8.—Experiment 56. 126 days. Dog 90-64. Removal of the epiphysis. The second bone from the right, 3, is the operated bone. There is a slight irregular growth from the cut end, which is not like the purposeful growth that occurs at the normal epiphyseal cartilage plate. Notice that it is shorter than the first bone on the right while normaly it is longer.

Experiment 59. 126 days. Dog 90-64. Cutting across the bone proximal to the metaphysis and removing the entire distal segment including the epiphysis. The second bone from the left, 4, is the operated bone. There has been an outgrowth of bone from the cut end, but it is pointed and thinner than normal. It is not like the purposeful growth that takes place from normal epiphyseal cartilage plate.

SUMMARY ON REMOVING ENTIRE EPIPHYSIS UP TO THE METAPHYSIS.

In these six experiments there are only two instances in which there is any appreciable increase in length. In these particular cases the growth is irregular and not like that which takes place in length growth in the epiphyseal cartilage plate. Thus it can be concluded that after removing the epiphysis there will be a failure of length growth of the remaining portion of the bone.

There is a certain tendency to encapsulate the cut bone end with tissue not unlike the articular cartilage.

TABLE XIV.

EXP. NO.	DOG NO.	DURATION	LOSS OF GROWTH	GROWTH OF OPERATED	GROWTH OF NORMAL
51	29-73	9 days	?	——	——
52	148-86	22 "	0.5 cm.	0.1 cm.	0.6 cm.
53	59-48	62 "	1.1 cm.	0.1 cm.	1.2 cm.
54	120-75	68 "	1.65 cm.	0.25 cm.	1.9 cm.
55	19-53	81 "	1.65 cm.	0.60 cm.	2.25 cm.
56	89-64	126 "	1.10 cm.	0.9 cm.	2.0 cm.

3. Cross Incision Through the Metaphysis and the Diaphysis with Removal of the Distal Fragment.

Method. After exposure of the bone a cross incision is made through the metaphysis or adjoining part of the bone and the entire distal segment is removed and not replaced.

Experiment 57. 16 Days. Dog 66-58.

Operation. Made an incision just proximal to the metaphysis and removed the distal portion of the metatarsal III. of the right hind foot. The part remaining measures 1.95 cm. The animal died at the end of 16 days.

Gross Findings. The healing is not very good. The end of the bone appears dry. The measurements are as follows: Metatarsal III., at autopsy, 2.2 cm.; metatarsal III., at operation, 1.95 cm. Thus there is 0.25 cm. increase in length.

Experiment 58. 67 Days. Dog 103-69.

Operation. Cut through the metatarsal III. of the left hind foot just proximal to the metaphysis and removed the distal segment. The total length is 2.85 cm., while the portion after removal measures 1.9 cm. The animal died at the end of 67 days.

Gross Findings. There is good healing. There is a pointed outgrowth of bone at the severed end. Upon longitudinal section the end is found to be covered with fibrous tissue. The cortex is found to extend beyond the narrow cavity on each side, thus giving the end a concave shape. The remainder of the bone is normal. The measurements are as follows: Metatarsal III., at end of experiment, 2.35 cm.; metatarsal III., at operation, 1.9 cm. Thus there is 0.45 cm. increase in length of the bone, which is mostly in the nature of a proliferation of the cortex. The normal increase is 4.2—2.85=1.35 cm.

Microscopical Findings. The articular end of the bone is surrounded by dense fibrous tissue. The cortex has become pointed in this region, and at the tip there is a mass of young cartilage tissue, again showing the tendency to encapsulate the cut end with cartilage. The cartilage cells from this tissue seem to have originated from the osseous trabeculae near the cut end. The fibrous tissue adjacent to the cartilage cells suggest somewhat the changes that take place in membraneous bone formation.

Experiment 59. 126 Days. Dog 90-64.

Operation. Cut across the metatarsal IV. of the right hind foot just proximal to metaphyseal region. Then removed the distal segment and did not replace. The portion remaining measured 1.85 cm. The animal was killed by chloroform at the end of 126 days.

Gross Findings. There is good healing. The end of the bone is covered with fibrous tissue. There has been an outgrowth of bone which is thinner than normal and pointed. The Roentgenogram shows the pointed outgrowth of bone and the general narrowing of the remainder of the bone. (See Fig. 8.) The measurements are: Metatarsal IV., at the end of experiment, 3.0 cm.; metatarsal IV., at operation, 1.85 cm. There has been 1.15 cm. of growth since the operation. This is of a pointed nature and possesses none or little marrow. It is an outgrowth of bone such as may occur upon the severed end of any bone and is not the definite longitudinal growth that takes place about the epiphyseal cartilage plate. The normal growth of bone has been about 1.5 cm.

SUMMARY ON CUTTING THROUGH PROXIMAL TO METAPHYSIS WITH REMOVAL OF THE DISTAL FRAGMENT.

After the removal of the distal segment of bone there is an outgrowth of bone from the cut end. This outgrowth is not like that occurring in the region of the epiphyseal cartilage plate as there is an entire lacking of the corresponding addition of the marrow cavity. It is more than likely that this outgrowth is like that which takes place along a periosteal remnant or that takes place in the region of the cut end of any young actively growing bone.

TABLE XV.

EXP. NO.	DOG NO.	DURATION	LOSS OF GROWTH	GROWTH OF OPERATED	GROWTH OF NORMAL
57	66-58	16 days	0	0.25 cm.	0
58	103-69	67 "	0.9 cm.	0.45 cm.†	1.35 cm.
59	90-64	126 "	0.4 cm.	1.15 cm.†	1.5 cm.

† Pointed.

GROUP VI. CROSS INCISION WITH REMOVAL OF THE PROXIMAL SEGMENT.

1. Through the Line of Cleavage of the Epiphyseal Cartilage Plate.

Method. The periosteum is cut about the epiphyseal cartilage plate and the epiphysis is separated in the line of cleavage. The proximal segment is then removed, leaving only the epiphyseal end of bone, including the epiphyseal cartilage plate.

Experiment 60. 30 Days. Cat 73-47.

Operation. Removed all but the epiphysis of metacarpal IV. of the left fore foot. The segment remaining measured about 0.5 cm. The animal died at the end of 30 days.

Gross Findings. There is good healing. The measurement of the operated bone was lost but from the general findings it can be presumed that there was no growth.

Experiment 61. 33 Days. Dog 113-73.

Operation. Separated at the natural line of cleavage after first incising the periosteum about the epiphyseal cartilage plate of metacarpal III. of the right fore foot. Then removed the entire basal portion. The total length of the bone is 1.9 cm., while the part remaining is .8 cm. The animal died at the end of 33 days.

Gross Findings. There is good healing. On longitudinal section a conical outgrowth of osseous tissue is found upon the free end of the bone. The epiphyseal cartilage plate is intact and is situated within this newly formed bone. The measurements are: Metacarpal III., at end of experiment, 0.85 cm.; metacarpal III., at operation, 0.8 cm. Thus, from the measurements, there is no evidence of increase in length. The normal increase in length is 3.0 cm—1.9 cm.=1.1 cm.

Microscopical Findings. The articular cartilage marrow and trabeculae of epiphysis appear normal. The epiphyseal cartilage plate is narrower than normal but has a fairly normal histological structure. There has been some separating of the bone in the metaphyseal region where there are ossifying cartilaginous columns which are lacking in some of the normal structure. The marrow is scanty. There has been some proliferative changes but not of the marked degree of the normal The growth is pointed and purposeless. (Fig. 9.)

Experiment 62. 44 Days. Dog 98-60.

Operation. The entire proximal end of the metacarpal III. of the right fore foot is removed up to the epiphyseal cartilage plate. The portion remaining measures 0.5 cm. The animal died at the termination of 44 days.

Gross Findings. The healing is good. The segment of bone crumbles somewhat upon making a longitudinal incision. Some of the epiphyseal cartilage plate is still present but the greater part can not be made out.

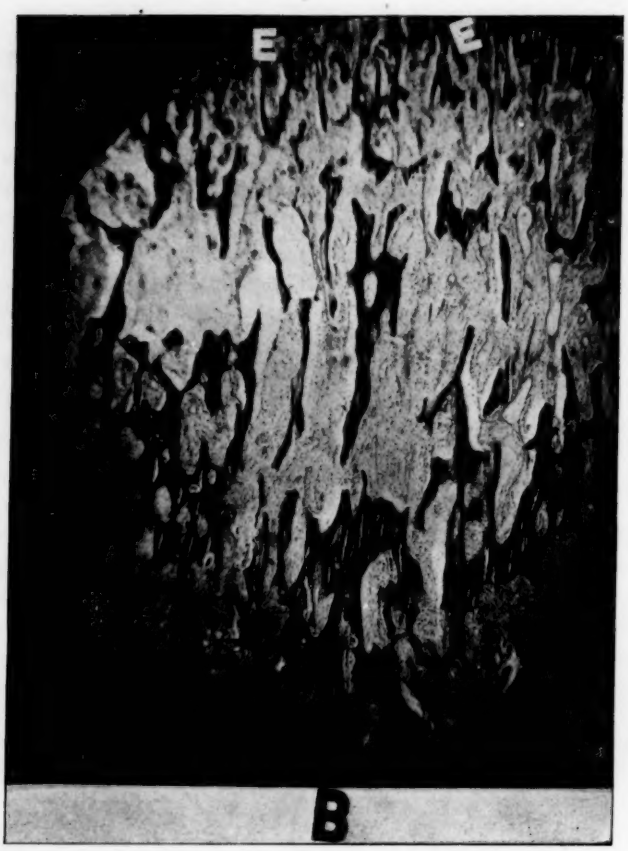

FIG. 9—Experiment 61. 33 days. Dog 113-73. Separation in the line of cleavage with removal of the entire basal portion of the bone, leaving the epiphysis. The microphotograph shows the irregular pointed outgrowth of bone that has taken place from the region of the epiphyseal cartilage plate. There is no evidence of a limiting cortex and the growth is of a purposeless nature. EE is the border of the epiphyseal cartilage plate (the remainder of the epiphysis could not be shown in the field); B, the pointed extremity of the new bone.

Microphotograph. Objective 1 inch. Ocular 2 inches. B. and L.

Experiment 63. 62 Days. Dog 125-75.

Operation. Removed the proximal portion of the metatarsal III. of the right hind foot. The entire length of the bone is 3.0 cm., while the part remaining is 0.7 cm. The animal died in 62 days.

Gross Findings. There is a slight outgrowth from the epiphyseal cartilage plate. The epiphyseal cartilage plate appears normal. The

remainder of the bone appears normal. The measurements are: Right metatarsal III., at end of experiment, 0.8 cm.; right metatarsal III., at operation 0.7 cm. Thus there is practically no growth of the operated bone. The normal growth is 1.0 cm.

SUMMARY OF REMOVING THE PROXIMAL END OF BONE UP TO THE EPIPHYSEAL CARTILAGE PLATE.

There has been practically a complete cessation of growth in all the experiments after such a procedure. The entire epiphyseal cartilage plate was left remaining, but growth ceased in spite of that fact. This failure of function of the epiphyseal plate can be ascribed to the great destruction of its direct blood supply, to injury to some of the cartilage cells, and loss of normal medium for the budding of the new cartilage columns.

TABLE XVI.

EXP. NO.	DOG NO.	DURATION	LOSS OF GROWTH	GROWTH OF OPERATED	GROWTH OF NORMAL
60	73-47*	30 days	——	——	——
61	113-73	33 "	1.05 cm.	0.5 cm.	1.1 cm.
62	98-60	41 "	0.85 cm.	0.15 cm.	1.0 cm.
63	125-75	62 "	0.9 cm.	0	1.0 cm.†

*Cat
†Estimated

2. Through the Metaphysis or Diaphysis.

Method. An incision is made across the metaphysis or diaphysis and the proximal fragment is removed.

Experiment 64. 15 Days. Cat 76-5.

Operation. Cut across the metaphyseal region of the metatarsal III. of the right hind foot and then removed the entire proximal piece. The part remaining measured 0.85 cm. The animal died at the end of 15 days.

Gross Findings. The healing is good. The measurements are: Metatarsal III., at end of experiment, 0.9 cm.; metatarsal III., at operation, 0.85 cm.=0.05 cm. Thus there has been no growth since the operation.

(To be continued.)

Society Meeting.

SECTION IN ORTHOPÆDIC SURGERY

NEW YORK ACADEMY OF MEDICINE

17-21 WEST 43RD STREET

CLINICAL MEETING IN CHARGE OF

THE NEW YORK HOSPITAL FOR RUPTURED AND CRIPPLED

Friday Evening, February 21st, 1919, at 8.30 o'clock sharp

ORDER

I. READING OF THE MINUTES.

II. PRESENTATION OF PATIENTS.

a. 1. Operative correction for deformity of the femur following fracture.
2. Operative correction for deformity of the radius following fracture.
Virgil P. Gibney, M.D.

b. 1. Operative treatment of pathologic dislocattion of the patella.
Royal Whitman, M.D.

c. 1. Operation for removal of fractured internal condyle of the humerus.
2. Operative correction for outward congenital dislocation of patella.
Henry Ling Taylor, M.D.

d. 1. Mild spasticity due to intracranial hemorrhage in adult; decompression; improvement. William Sharpe, M.D.

e. 1. Fracture of the humerus
2. Fracture of the tibia and fibula.
Charlton Wallace, M.D.

f. 1. Presentation of orthopædic case. B. H. Whitbeck, M.D.

g. 1. Fracture of the spine.
2. Genu recurvatum and knock knees in adult, cured by operation.
Samuel Kleinberg, M.D.

h. 1. Fracture dislocation of elbow. W. L. Sneed, M.D.

i. 1. Presentation of cases of anterior poliomyelitis.
William Frieder, M.D.

j. 1. Lantern demonstration of bone lesions. P. Ashley (by invitation.)

k. 1. Resection of right elbow of adult for ankylosis in bad position.
George Barrie, M.D.

III. DISCUSSION.

REGINALD H. SAYRE, M.D., *Chairman*
14 West 48th Street

GEORGE BARRIE, *Secretary*
15 East 48th Street

Notice.

TO THE MEMBERS OF THE AMERICAN ORTHOPEDIC ASSOCIATION:—

Dr. H. Augustus Wilson, the representative of the American Orthopedic Association on the Committee of Arrangements of the Congress of Physicians and Surgeons, announces that the Annual Meeting of the Association will be held in Atlantic City on Monday and Tuesday, June 16 and 17, 1919, directly following the meeting of the American Medical Association. The Hotel Chalfonte will be the headquarters for both meetings.

Members should make early reservation of rooms.

Current Orthopaedic Literature

Numerals at head of each abstract are for use in connection with the official "Classification of Orthopædic Literature," published in the JOURNAL for January, 1917, reprints of which are obtainable from the JOURNAL office.

III. ORTHOPAEDIC OPERATIVE, POST OPERATIVE AND ADJUVANT TECHNIC.

III, 3, b.

NEW OPERATION FOR SUBSTITUTION OF THE THUMB. J. L. Joyce, *British Journal of Surgery*, April, 1918.

The author advises substitution of the ring finger of the opposite hand for the thumb lost as a result of injury or disease and he uses a new method of applying a pedunculated flap. The steps of the operation are briefly the following:

1. Preparation of the bed for the reception of the new metacarpal bone and exposure of the proximal end of the divided tendon of the old thumb.
2. Dislocation of the ring finger of the opposite hand at the metacarpal phalangeal joint, with division of the soft tissue at the base of the radial side of the proximal phalanx, division of the extensor and flexor tendon and the preservation of the nutritive flap on the ulnar side of the finger.
3. Fixation of the new metacarpal bone (proximal phalanx of the ring finger) in its bed, union of the tendon and nerve, suture of the incision and fixation of the hand.
4. Division of the nutritive flap two months later.

All these steps are more minutely described and the end result of the case is given in a number of photographs. Aside from the fact that the cosmetic result is extremely gratifying, the functional result obtained, as illustrated by photographs, is nothing less than astounding and it is safe to say that this case is the most remarkable one reported in literature on thumb plasty from Nicoladoni to the present time.—*A. Steindler, Iowa City, Ia.*

III, 7.

AUTOPLASTIC NERVE TRANSPLANTATION IN THE REPAIR OF GUNSHOT INJURIES. By Leo Mayer. *Surg. Gynec. & Obstet.*, November, 1918.

The author describes a method of bridging nerve gaps with autogenous sensory nerve. The scar tissue about the injured nerve is dissected away, the length of gap noted, then the external saphenous vein is exposed, and in intimate association with it is found the external saphenous nerve. If the injured nerve is 4 times the diameter of the external saphenous nerve, enough external saphenous nerve is dissected out to furnish a four strand cable approximately the diameter of the injured nerve. The nerve is held in a special Bunnell clamp (S. S. White matrix steel gouge .003). A single stitch holds the four strands of the cable together. Fine silk sutures hold each strand of the cable at each end to the abutting ends of the injured nerve.

The advantages of the transplantation method are:

1. There is no excessive tension on the line of suture.
2. Immobilization of the limb in a flexed position, with subsequent stretching, is not necessary.

3. The technique, when practiced, is by no means difficult.
4. The clinical results are superior, in the author's opinion, to any other form of nerve bridging operation.—*Leo C. Donnelly, Detroit.*

III, 12.

SELF RETAINING RETRACTOR FOR USE WITH ALBEE BONE OUTFIT. Lowman and Pratt. *Surg., Gynec. and Obstet.* Dec., 1918.

The retractor is made of two arcs of spring steel fixed together by lateral lips. The toothed portions are rounded and broad, giving wide, even retraction. The retractor encircles the limb, the weight of the limb produces the retraction. The lateral lips furnish a simple friction lock whose function is increased by any force exerted upon the two parts of the retractor, except exactly in the direction of its arc by means of which the retractor is opened and closed.

Advantages are simplicity, durability, cheapness, produces retraction and depression, does away with an assistant, keeps extra hands out of the wound, leaves bone in higher plane than surrounding tissue, lessens danger of motor entangling in towels, gives a better exposure, also removes one assistant, allowing clinic to see better.—*Leo C. Donnelly, Detroit.*

IV. RESEARCH IN BONE GROWTH AND REGENERATION. SKELETAL ANATOMY AND PHYSIOLOGY.

A STUDY OF THE DEVELOPMENT OF THE EPIPHYSIS. By Philip H. Kreuscher. *Surg., Gynec. and Obstet.* Nov., 1918.

In the early periods of bone development the epiphysis is entirely cartilaginous; later there is a gradual disappearance of the cartilage until only a shell remains, surrounding the cancellous epiphyseal bone and marrow. The cartilage at one end persists to form the articular cartilage, while at the inner boundary if forms a part of the epiphyseal cartilage line. The epiphyseal cartilage line ceases to functionate, either when transplanted by itself, or with a small or large piece of adjoining bone, or even transplanted as an entire bone. The loss of growth probably is due to the interference with the vascular supply from the diaphyses to the epiphyseal cartilage line.

A center of ossification in the distal epiphysis of the femur is nearly constant at birth, the four parts of the occipital bone are separate, the mastoid portion of the temporal is partially ossified, the lateral halves of frontal still separate at birth. The vertebrae are ossified in all essential parts, but epiphyses still separated by cartilage. In some cases the proximal epiphysis of humerus is ossified at birth, center for external condyle at thirteenth to fourteenth year, for external epicondyle 8th to 10th, internal condyle 5th to 6th, internal epicondyle 8th to 10th. The metacarpal and phalangeal bones are ossified at birth, cuneiform appears at third year, trapezium and semilunar at 5th, scaphoid at 6th, trapezoid at 8th, pisiform at 12th. At birth the ossified portion of os pubis usually surrounds only a portion of anterior boundary of obturator foramen; symphysis and upper portion of horizontal ramus remain cartilaginous.

No ossification centers are present at birth in the upper end of the femur, the one for the head coming during the first year, great trochanter at third year, lesser trochanter 13th to 14th year. The centers for the proximal epiphyses of tibia, fibula, cuboid and 3 cuneiforms usually are not present at birth.

The os calcis develops by a single center appearing at 6th month of foetal life, the center for the epiphysis at 9th year. The astragalus at 7th month.

cuboid at 9th, external cuneiform 1st year, internal at 3rd year, middle cuneiform and scaphoid at 4th year. Growth and development is influenced largely by the health of the mother and foetus; syphilis, rickets, osteogenesis imperfecta, etc., retarding.

Conclusions.

1. That a thorough knowledge of the normal structures and their time of appearance is necessary intelligently to treat the abnormal conditions.

2. That fractures at the epiphyseal lines should be recognized early and reduced completely to avoid deformities.

3. That injuries about the joints in the young must never be treated lightly or haphazardly.

4. That operative injury of the epiphyseal line is inexcusable with our present knowledge of its importance.—*Leo C. Donnelly, Detroit.*

V. TUBERCULOSIS.

V, 2, *a*.

TUBERCULOUS DISEASE OF THE HIP JOINT. H. J. Gauvain. *The Lancet.* November 16, 1918.

The author describes a sign which is significant in determining activity in apparently quiescent cases of hip disease. If the femur is grasped firmly in the region of the condyle it may be gently rotated within the acetabulum inward and outward to a definite degree. If this range of motion is exceeded passively it results instantly in spasmodic muscular contractions not confined to muscles about the joint but extending to the abdominal muscles. Quite a gentle and painless sharp rotary movement is sufficient to provoke this reflex spasm of the abductor muscles. The value of the sign lies in the fact that without such definite indication of activity ambulatory treatment may be permitted too early with great risk of relapse.

While failure to elicit the sign is a certain indication that there is no muscular spasm about the affected joint, that alone does not justify assumption that disease is finally arrested. If recumbency and immobilization are enforced and the sign of activity described cannot be demonstrated, not only may a favorable prognosis be given in general, but also a very useful range of movement in the joint attacked may be anticipated.

The sign also has diagnostic significance in early cases of tuberculous hip disease. It is one of the many signs of tuberculosis, but it affords confirmative evidence of active inflammation about the hip joint, in conjunction with other signs of tubercular disease of the hip.—*A Steindler, Iowa City, Ia.*

X. CONGENITAL ABNORMALITIES (other than dislocations.)

X, 2, and XVIII, 2.

COMMON LESIONS PRODUCING BACKACHE. Wm. F. Shackleton. *Surg., Gynec. and Obstet.* December, 1918.

The author briefly reviews the classification of lesions of the lumbo-sacral and sacro-iliac joints. He has carefully dissected this region in 26 cadavers. The one constant finding was that the lumbo-sacral cord directly overlies the linea innominata and that it is not protected by underlying soft parts. The transverse process of the last lumbar vertebra varies in length from ½ cm. to 4 cm., and in shape from a rounded point to a broad fish-tail process. The distance between the processes and the ilium varies from fusion to 6 cm. The anomalies of the processes which become pathological seem to develop during years of hard labor. The factors involved in the

production of pain seem to vary. The transverse process may impinge on the ilium, and acting as a fulcrum, separate the sacro-iliac joint. Hyperplasia of the soft parts may involve the nerve or the process may act as a cervical rib on the brachial plexus.

Treatment resolves into constitutional, palliative, and radical surgical procedures. In chronic conditions, belts, girdles, corsets and casts bear practically the same relation in the treatment of these cases that the application of a truss bears to hernias.—*Leo C. Donnelly, Detroit.*

XI. ACUTE INFECTIONS OF JOINTS AND BURSAE.

XI, 1.

LACERATION AND INFECTION OF JOINTS IN CHILDREN. A. Mitchell. *British Journal of Children's Diseases.* July—September, 1918.

The author emphasizes the importance of this class of cases and the unsatisfactory results of treatment. He stresses the following points in treatment:—Complete immobilization with extension, excision of all infected tissue including synovial membrane in the wound tract, the removal of foreign bodies, and the washing out of all debris and clots with a weak antiseptic or salt solution. The drainage tube and the Bipp dressing are recommended. Histories of three cases with complete functional results are given. The use of the Robert Jones splints and plaster of Paris for fixation is recommended. The joints are fixed for about a month after the wounds are healed. Passive motion and massage followed.—*Edward Z. Holt, Atlantic City.*

XII. CHRONIC INFECTIONS OF JOINTS AND BURSAE (non-traumatic).

XII, 3 *a*.

TYPHOID SPINE. Sir Wm. Osler *Bulletin of Canadian Army Med. Corps.* September, 1918.

Sapper C, paralyzed for nearly two years, yet he walked in ten minutes. What a case for Lourdes or for our own Canadian St. Anne de Beaupré.

In February, 1916, Sapper C had an ordinary attack of typhoid fever. Convalescence was slow. In October he began to complain of pain in the back, and stiffness. From that time he became progressively incapacitated, —was never out of bed for two years.

On examination patient showed excessive nervousness and apprehension. —fearful lest he be moved,—well nourished, no mental disturbance, pupils widely dilated. When stripped a profuse blush covered the body and an unusually persistent goose skin. Any attempt to move caused agonizing pain in the back. Legs looked normal, no wasting, no disturbance of sensation. Spine was straight, there was no projection or prominence. Pressure was exceedingly painful below the mid-dorsal and lumbar spine. Toes could be moved and ankles flexed.

Sensation. A band of extreme hyperæsthesia extended around the body a hand's-breadth wide below the costal margin,—more marked in front.

Reflexes. Knee jerks exaggerated. Nothing else of note. X-ray plates showed a spine normal in every particular.

In May, 1917, Sapper C. was transferred to the Duchess of Connaught Hospital at Cliveden. Here a spinal jacket gave great relief from the pain and the general condition was much improved, but it was found impossible to get the patient to sit up, and every attempt at moving the legs brought

on a clonic spasm. After eight months he was transferred to National Hospital, Queen's Square, London, to the care of Dr. Yealland, C.A.M.C., formerly of the Out-patient Psychopathic Department of the Toronto General Hospital.

Dr. Osler goes on to discuss his former opinion that typhoid spine was always a functional neurosis, but states that he changed his mind on seeing a case with Dr. Runhardt in 1902, when there was well marked and painful swelling just above the sacro-iliac articulation, though no suppuration followed. A number of other cases are referred to where examination and x-ray pictures have shown the usual signs of a definite spondylitis.

In support of the view that typhoid spine is essentially a neurosis, Dr Osler cites a case shown at Johns Hopkins Medical Society in 1901, emphasizing the following features. First, a state of neurasthenia with vasomotor changes and often the definite stigmata of hysteria. Secondly, stiffness of the back persisting for weeks or months, associated with pain, often of an agonizing character. Third, pain on pressure over certain spinous processes. Fourth, a negative local examination. Lastly, a prompt recovery with the use of the Paquelin cautery and measures directed to the neurotic condition.

The case of Sapper C. strongly supports this view. After the spinal jacket was removed, still very neurotic, spine absolutely rigid, he could not be induced to move or sit up; but new surroundings, a new mind and very skillfully applied methods did in ten minutes what a year's treatment failed to do—put him on his feet, walking well, looking well and very happy to be so.

Cases of typhoid spine may be grouped in three categories: First, those in which the hysterical features predominate; secondly, cases with fever, pain, rigidity, and evidence of nerve root involvement; and thirdly, a group of cases with definite objective changes in the spine, as shown by x-ray pictures as well as by examination.—*F. P. Yorston, Montreal.*

XII, 6.

Case of Loose Body in Knee Joint. P. B. Roth. *Lancet.* September 28, 1918.

A Jones operation followed a typical history of a loose body in the knee joint. The body was removed. A subsequent X-ray showed another shadow posterior to that caused by the loose body. This proved to be a sesamoid bone in the gastrocnemius. The author differentiates between a loose body in the knee joint and a sesamoid in the gastrocnemius. A sesamoid when seen from the side is oval shaped, with its long axis placed verfically. It is as dense to X-rays as is the densest part of the femur and is situated behind a line joining the most posterior portion of the tibial head and the femoral condyles. This paper is extremely interesting.—*Edward Z. Holt, Atlantic City.*

XIV. PARALYTIC CONDITIONS.

XIV, 3.

Cerebral Spastic Paralysis. M. E. Blahd, and Walter G. Stern. *American Medical Association Journal.* November 2, 1918.

This paper gives a brief but very complete recital upon the subject of cerebral spastic paralysis from the etiology to the treatment. All cerebral lesions, such as clots, tumors or cysts, should be attacked early if any result is to be expected. Cases of long standing or very extreme involvement do not hold out hope of much improvement by intra-cranial interference.

Resection of the posterior nerve roots has been very beneficial in many cases. This relieves the spastic component and allows the paralytic component to be improved by education. The possibility of nerve regeneration, and so a bridging of the gap, must be taken into consideration. Forcible correction of deformities is sometimes useful, but often very painful to passive motion afterward.

Tenotomy may be employed, but lengthening of the tendon is better, because the balance of opposing groups of muscles is thereby much more certain. Tenotomy with too great an over-correction is most often a disappointing failure.

By far the most important part of the treatment is the education which must follow operative procedures. This should be followed carefully for many years under competent supervision. Systematic muscle training as well as vocational practice in schools established for the purpose are advised.—*Harold A. Pingree, Portland, Me.*

XVI. METABOLIC DISEASES AND DISEASES OF INTERNAL SECRETION.

XVI, 8.

Osteitis Deformans; Report of Two Cases. S. R. Leahy. *Neurological Bulletin.* August, 1918.

The author reviews the history of osteitis deformans and presents elaborate histories of two cases. He believes Paget's disease to be due to a disturbance of the secretions of the endocrinous glands. The condition differs from acromegaly chiefly in that the bones of the face, hands, and feet are not affected. The skull does not show the marked thickening in acromegaly that is so characteristic of this disease. An extensive bibliography accompanies the article. *Edward Z. Holt, Atlantic City.*

XVIII. STATIC OR POSTURAL DEFECTS.

XVIII, 6.

Static Defects of the Feet. Edward A. Rich. *American Medical Association Journal.* December 14, 1918.

Major Rich advocates the use of certain set measures for determining the condition of the arches of the foot itself as well as the relation of the leg to the foot through the medium of the ankle joint. He uses the Feiss scaphoid scale to ascertain the elevation of that bone. This scale corresponds to Feiss's line and determines whether the internal arch is too high, too low, or just about normal.

The second means is a map of the weight-bearing foot by means of an ink impression which gives us the bearing surface, and this is combined with a pencilled outline which shows us the degree of pronation as well as the extent to which valgus of the ankle has taken place. By means of these planes we are enabled to judge the type of foot disability as well as its extent. The weight must be carried on that part of the foot by which nature intended it should be borne.

These changes are accomplished by the insertion of variously shaped leather wedges between the layers of the boot sole. The cardinal points are few and simple.

Major Rich's years of civil practice, as well as his large experience in the army, seem to justify a consideration of his opinion. The article is furnished with many excellent illustrations.—*Harold A. Pingree, Portland, Me.*